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**ontario hydro
research division**

**KIPLING COMPLEX
NEW ANALYTICAL CHEMISTRY LABORATORY
(BUILDING KJ) IN SITU STRESS
MEASUREMENT PROJECT FOR C₁₄ WELL
(BOREHOLE KJ)**

ABSTRACT

A series of 12 in situ stress measurements were made on the proposed site of Building KJ. Six rocks were also subjected to geomechanical testing in the laboratory. The results of these tests will be incorporated into the foundation study of Building KJ.

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**KIPLING COMPLEX
NEW ANALYTICAL CHEMISTRY LABORATORY (BUILDING KJ)
IN SITU STRESS MEASUREMENT PROJECT FOR C₁₄ WELL
(BOREHOLE KJ)**

1.0 INTRODUCTION

A series of in situ stress measurements were made on the proposed site of building KJ at Ontario Hydro's Research Complex on Kipling Avenue, Toronto during November, 1989. The purpose of this study was to measure the existing rock stresses in borehole KJ as part of the foundation design for building KJ whose location is shown in Figure 1.

Laboratory tests were scheduled to be performed on three rock cores from this borehole in order to determine Young's modulus of elasticity, Poisson's ratio and the ultimate compressive strength. Packer testing was also scheduled to be performed in the borehole during the spring of 1990 to determine the hydraulic characteristics of the mass.

2.0 TEST PROCEDURE

The test method used to measure the in situ stress was an overcoring method using a United States Bureau of Mines Borehole Deformation Gauge (USBM gauge) applied in accordance with the American Society for Testing of Materials (ASTM testing guideline

ASTM 4623) guidelines. The formulae used in this analysis are:

$$P = \frac{E}{6d(1-\gamma^2)} U_1 + U_2 + U_3 + \frac{1}{\sqrt{2}} [(U_1 - U_2)^2 + (U_2 - U_3)^2 + (U_3 - U_1)^2]^{1/2}$$

$$Q = \frac{E}{6d(1-\gamma^2)} U_1 + U_2 + U_3 - \frac{1}{\sqrt{2}} [(U_1 - U_2)^2 + (U_2 - U_3)^2 + (U_3 - U_1)^2]^{1/2}$$

$$\theta = \frac{1}{2} \tan^{-1} \frac{\sqrt{3}(U_2 - U_3)}{2U_1 - U_2 - U_3}$$

- where
- P = major secondary principal stress
 - Q = minor secondary principal stress
 - θ = angle between U_1 and P turned in a counterclockwise direction
 - E = the Young's modulus of elasticity of the material in which the stress measurements are made
 - γ = Poisson's ratio of the material in which the stress measurements are made
 - d = the diameter of the hole

U_1, U_2, U_3 = are the strains that have been measured on the three separate gauge axes

The relationship between P, Q and θ are shown in Figure 1 in Appendix 1.

3.0 TEST LOCATIONS

The original test locations were based on an assumed depth of bedrock of 5.00 to 6.00 m as indicated by previous drilling at the site. The conditions encountered in the KJ borehole indicated that the soil-bedrock contact was at a depth of 7.28 m with auger refusal at 8.05 m. The start of the more component rock was assumed being at 8.05 m and the depths for the overcore tests were changed accordingly to:

Test	Depth From Surface (m)	Depth Below Soil/Rock Contact (m)
1	11.05	3.00
2	12.55	4.50
3	18.05	10.00
4	28.05	20.00
5	33.05	25.00
6	38.05	30.00

The rock at this site is a medium to dark grey, Ordovician age shale named the Georgian Bay Formation that slakes rapidly on exposure to air and water. This rock is notorious for being very difficult to test in and for this reason it was believed that it would be necessary to repeat several of the tests due to core breakage during the overcoring.

4.0 TEST RESULTS

The results of the overcoring tests are presented to Table 1 and the test locations are given in Figure 3. The geologic log of the borehole is given in Figure 2 and the log from the borehole camera survey is given in Appendix 2. The overcore curves are contained in Appendix 3 and the biaxial test curves are in Appendix 4. Every effort was made to

include all pertinent data in the borehole log in accordance with established Ontario Hydro procedures. The original request that all borehole logs be recorded in accordance with CSA standard A119.5 "Recording of Borehole and Test Pit Information" could not be met because according to the CSA Info-centre this standard is not listed on their files.

The major secondary principal stress (P) ranges from 1.15 MPa to 11.52 MPa in compression while the minor secondary principal stress (Q) ranges from 0.52 MPa to 5.48 MPa. The average value of Young's modulus of elasticity is very low for this material ranging from 6,588 MPa to 17696 MPa. Due to the poor quality of the overcores from damage, sustained during core recovery only a few of the cores were suitable for testing. Following standard Ontario Hydro practice for stress testing at a new site double tests were attempted, that is a second test was performed immediately below the first test, in order to verify the results of the first test. The quality of the rock at this site was very poor for overcoring measurements and as a result some of the tests had to be repeated as many as five times before even one successful test was achieved. Tests 1, 3, 6, 8, 9 and 12 yielded overcores suitable for testing and so in the cases of tests 2, 4, 5, 7, 10 and 11 which were located very close to tests that had testable overcores it was decided to assume that the Young's modulus value applied to both tests. The tests were grouped as (1, 2, 4, and 5), (6 and 7), (9 and 10) and (11 and 12) for Young's modulus values. The test 3 Young's modulus of elasticity result was used only for test 3 because it was much lower than other biaxial results and may, not be truly representative of the rock mass.

During the drilling of the borehole certain harder, lime rich horizons were found to contain partially healed joints which may have influenced the test results. The tests which were known to have joints near them were tests 2, 5, 8, 9, 10, 11 and 12. The relationship of these joints to the stress results are shown in Figures 4 - 11.

The dip direction of the joints near tests 8, 9 and 10 are uncertain due to the extensive core grinding which occurred along bedding planes between the joint locations and the oriented overcore. The joint traces are plainly visible in the harder limey layers but are very difficult to follow in the shale layers. In areas where the joint strikes and dip directions in horizons above and below these tests are known they appear to be fairly consistent. In view of this consistency of joint orientation a dip direction of 253° was assumed for the joints near tests 8, 9 and 10.

The P orientations of all tests are given in Figure 12. The results indicate three (3)

clusters of stress orientations:

Group 1 - Tests 1, 2, 3, 5
Group 2 - Tests 4, 6, 7, 8, 9 and 10
Group 3 - Tests 11 and 12

The reason for the existence of these groupings is not fully understood at present but the northwest -southeast trends of groups 1 and 2 is unusual based on the results from other stress measurement studies in southern Ontario. Group 3 which has an orientation of northeast - southwest appears to fit the regional trend. All tests with the exception of test 5 have reasonable test curves. The test 5 curve shows evidence of gauge vibration which could have influenced the test results. This may explain the difference in the orientation of P between tests 4 and 5.

5.0 CORE TESTING

Due to the difficulty in obtaining suitable test zones for stress measurements in borehole KJ very little core was left for laboratory testing and the remaining core had slaked extensively. Fortunately, two other boreholes were drilled through the same rock mass in building KG, as part of another project, and cores from these boreholes were tested for Young's modulus of elasticity Poisson's ratio and ultimate compressive strength. The KG boreholes are located fairly close to the KJ site and should be representative of the rock strength characteristics that would be found in borehole KJ. The location of the KG boreholes are shown in Figure 13 and the laboratory test results are given in Table 2. These tests were run in accordance with ASTM designations D2938, D3148-86, D4543, E4 and E122.

The results show that the shale is a very low strength rock with a low value for Young's modulus of elasticity. The one sample from a lime-rich layer was run for comparison and had much higher compressive strength and Young's modulus values. The Young's modulus values for the test specimens are of a similar magnitude to those measured in the overcoring tests. The load-deformation curves for these specimens are contained in Appendix 5.

6.0 SUMMARY

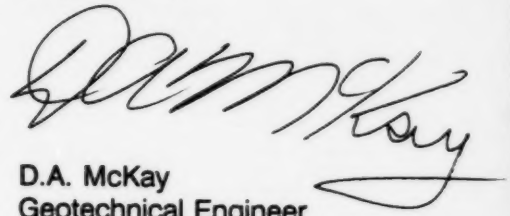
The rock stresses measured in borehole KJ indicate that there are three distinct zones of stress in the rock mass at the future construction site. These in situ stresses when considered in conjunction with the physical parameters of the rock indicate that significant plastic deformation may occur in a permanent well to the extent that the integrity of the well lining could be compromised unless these large deformations are accounted for in the design.

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TEST NO.	DEPTH m	ELEV. m	P MPa	Q MPa	P/Q	YOUNG'S MODULUS MPa	ATTEMPTS	AZIMUTH OF P	COMMENTS
1	13.65	101.88	6.43	3.12	2.06	10437	5	096	
2	15.04	100.49	11.51	4.00	2.88	10437	2	100	E FROM TEST 1
3	16.90	98.63	3.95	3.37	1.17	6588	1	075	LOW E DUE TO POSSIBLE CRACK
4	17.15	98.38	1.62	0.77	2.11	10437		121	E FROM TEST 1
5	17.65	97.88	1.15	0.52	2.22	10437		087	E FROM TEST 1
6	23.09	92.44	2.74	2.13	1.28	13023	2	146	
7	23.33	92.20	5.54	4.69	1.18	13023		145	* E FROM TEST 6
8	28.03	87.50	6.63	5.48	1.21	14416		129	
9	28.40	87.13	7.24	5.01	1.45	15344		147	
10	33.09	82.44	1.45	0.82	1.77	15737		141	
11	38.00	77.53	5.97	2.28	2.62	17696	3	050	E FROM TEST 12
12	38.35	77.18	6.74	0.73	9.20	17696		046	

Based on approximate ground elevation at site of 379.05 ft. (115.53m) from OHDRNG P3-506
(REV 7) 12/09/80

TABLE 1

KIPLING COMPLEX BUILDING KJ STRESS TEST RESULTS

BOREHOLE NO. IN BLDG KG	DEPTH			ROCK TYPE	YOUNG'S MODULUS OF ELASTICITY MPa	POISSON'S RATIO	ULT. COMP. STRENGTH MPa
	Ft	In	m				
1	58	0	17.68	SHALE	3640	0.09	10.99
1	73	6	22.40	SHALE	29004	0.09	14.78
1	74	0	22.55	SHALE	4891	0.09	10.76
2	43	0	13.11	SHALE	2480	0.09	14.44
2	63	0	19.20	LIMESTONE	59988	0.19	169.29
2	75	11	23.14	SHALE	13590	0.15	15.83

TABLE 2
UNCONFINED COMPRESSIVE STRENGTH TEST RESULTS

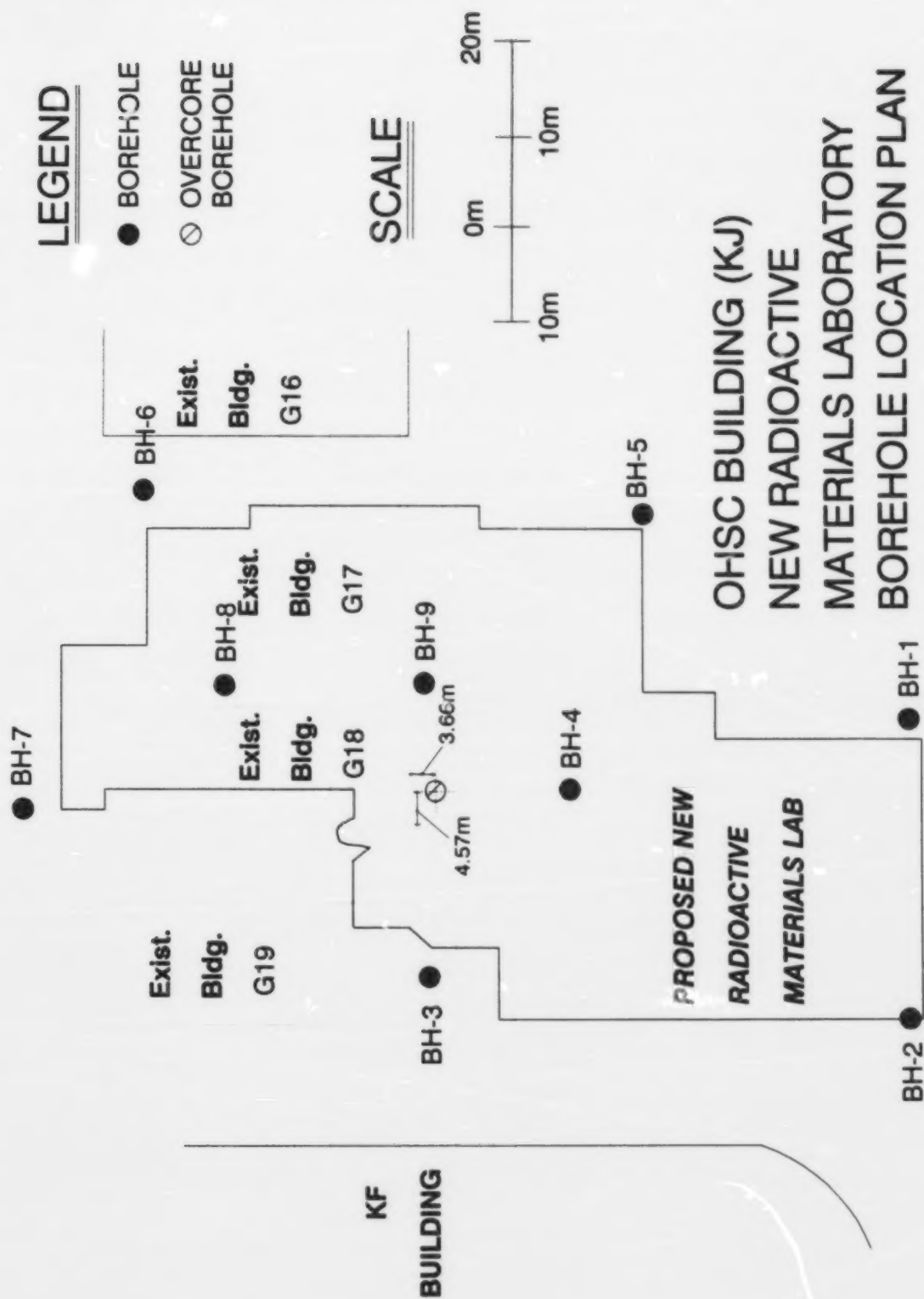


Figure 1

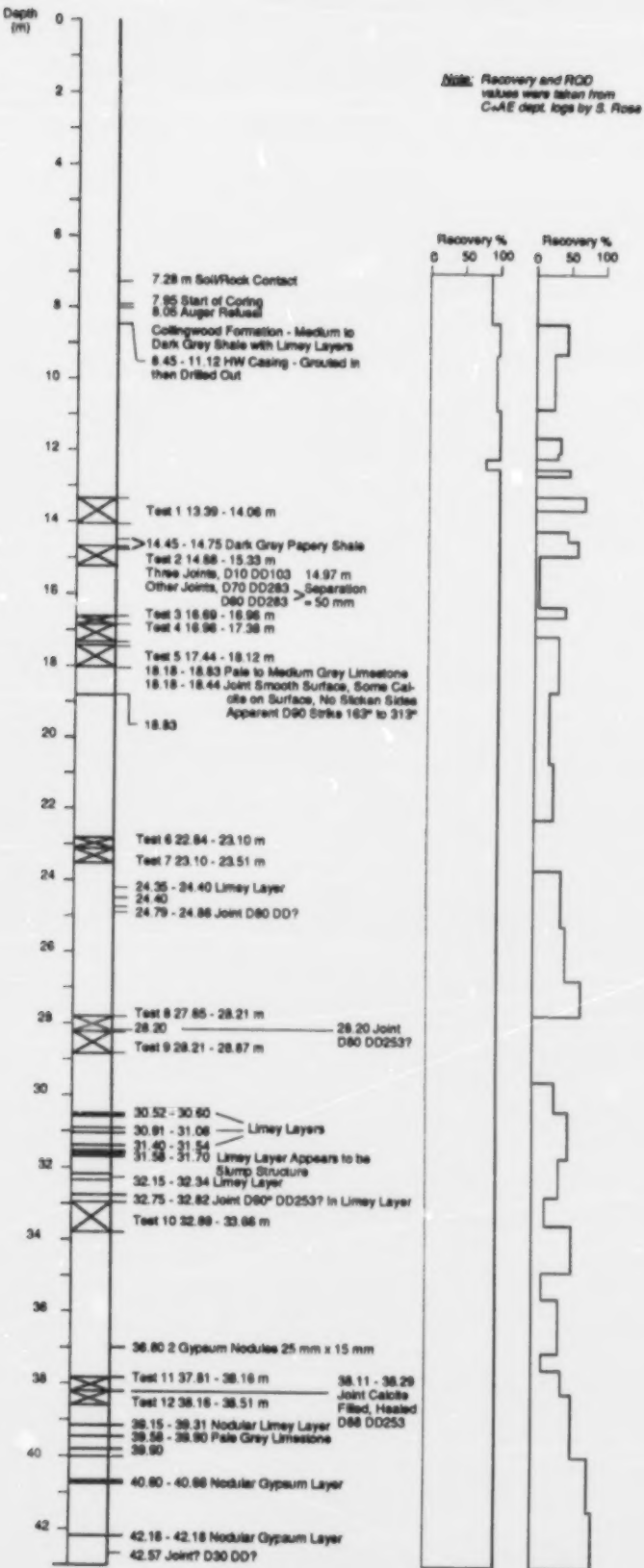


FIGURE 2
BH1
KIPLING COMPLEX
BUILDING KJ - COLLAR ELEV
PLUNGE: -90°

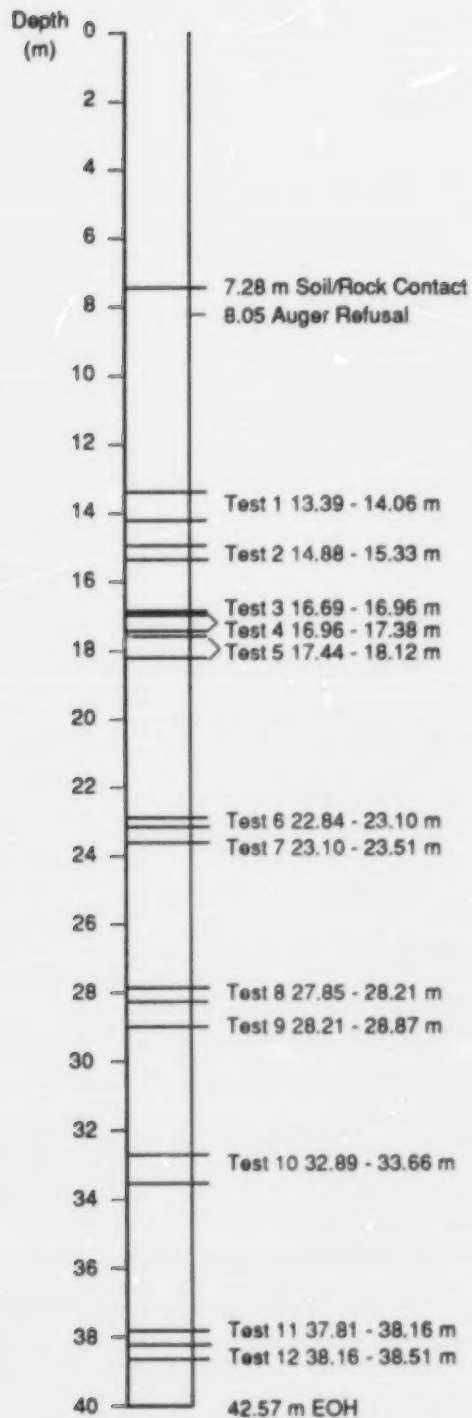


FIGURE 3

KIPLING COMPLEX
BUILDING KJ
NOVEMBER, 1989
OVERCORE TEST LOCATIONS

183240-C16-RD

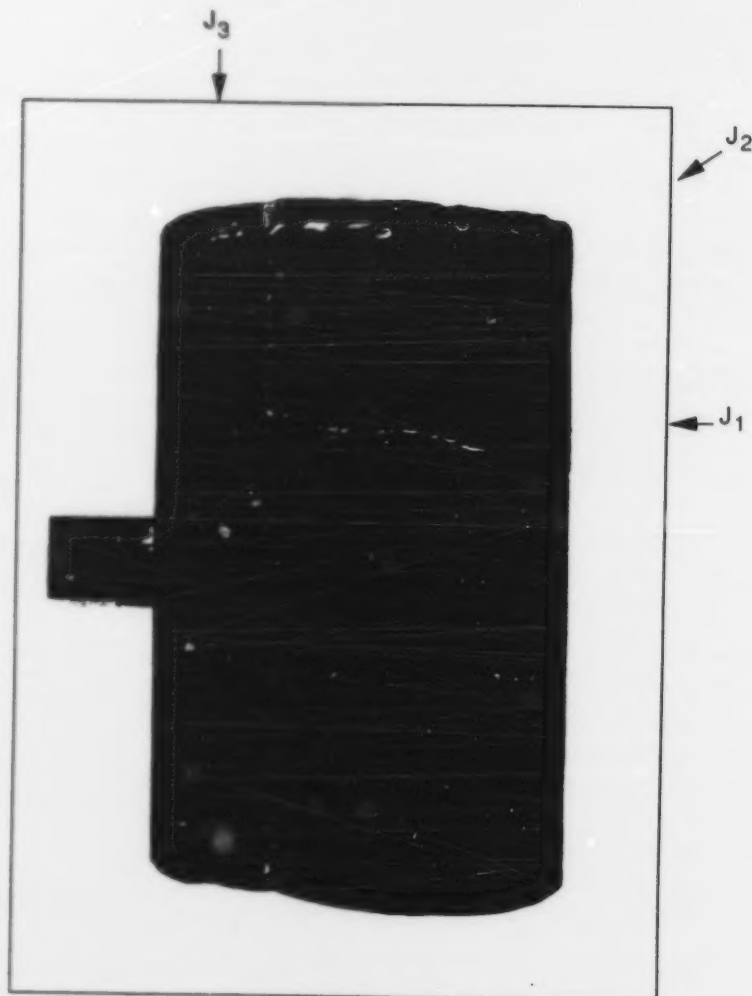


FIGURE 4

**JOINTS IN TEST 2
OVERCORE, DEPTH 14.96 - 15.05 m**

J ₁	D10	DD103
J ₂	D80	DD283
J ₃	D70	DD283

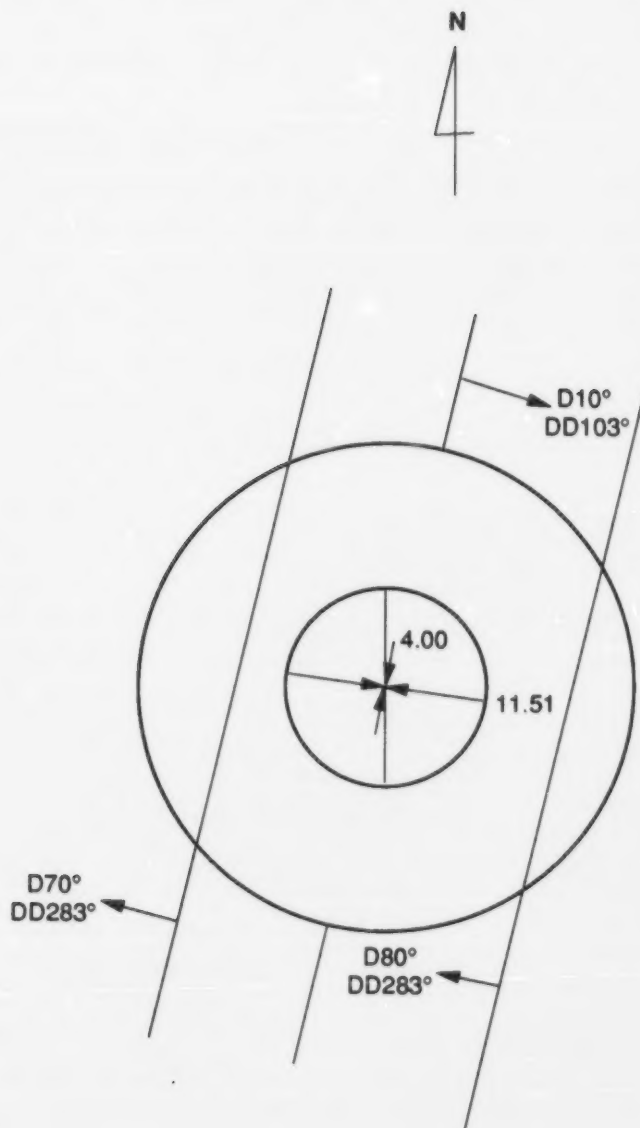


FIGURE 5

TEST 2
DEPTH 14.88 - 15.33 m
STRESS MAGNITUDES ARE IN MPa

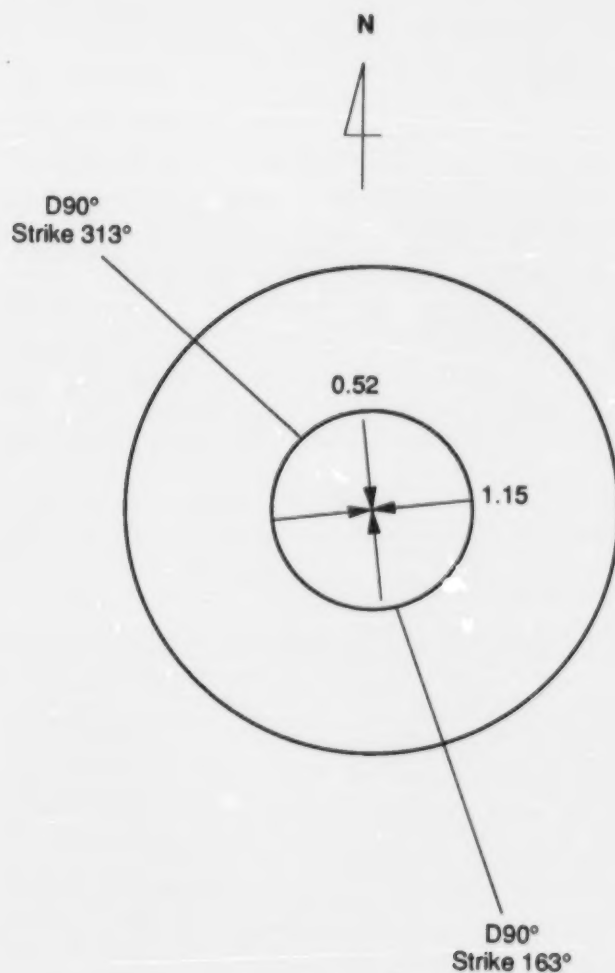


FIGURE 6

TEST 5
DEPTH 17.44 - 18.12 m
STRESS MAGNITUDES ARE IN MPa

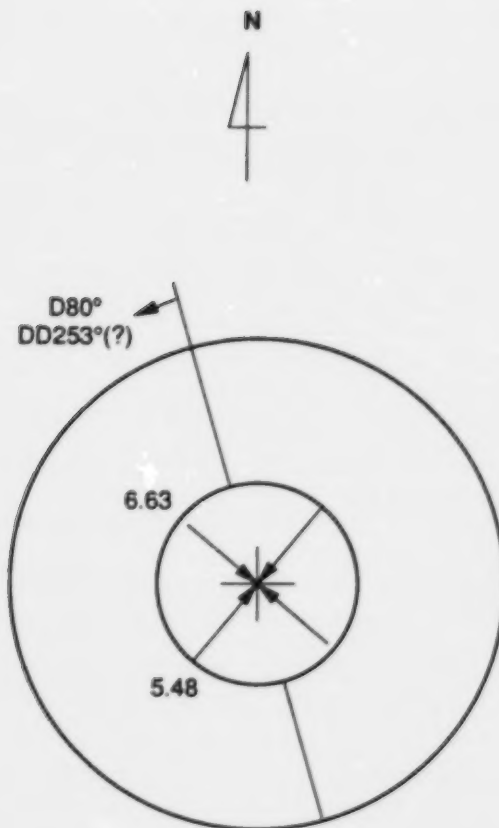


FIGURE 7

TEST 8
DEPTH 27.85 - 28.21 m
STRESS MAGNITUDES ARE IN MPa
(?) Indicates Assumed Value

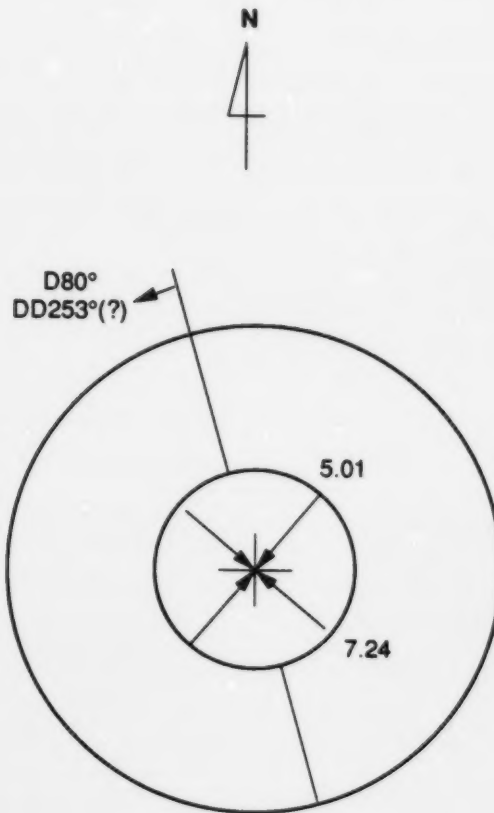


FIGURE 8

TEST 9
DEPTH 28.21 - 28.87 m
STRESS MAGNITUDES ARE IN MPa
(?) Indicates Assumed Value

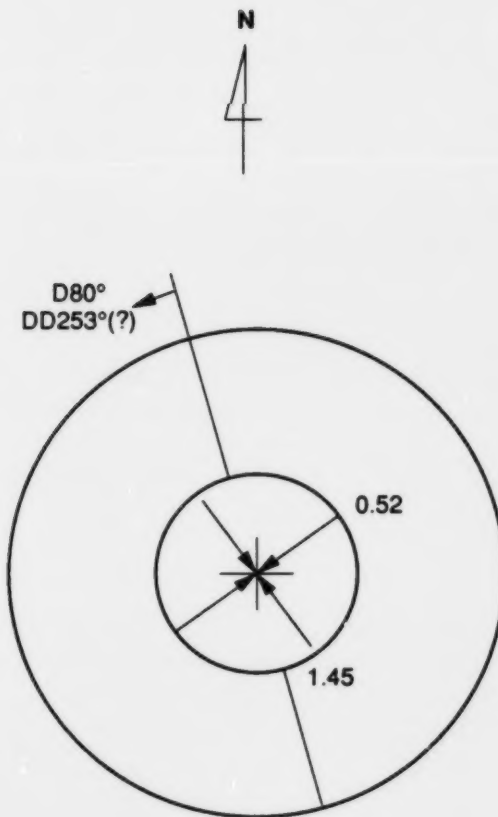


FIGURE 9
TEST 10
DEPTH 32.89 - 33.66 m
STRESS MAGNITUDES ARE IN MPa
(?) Indicates Assumed Value

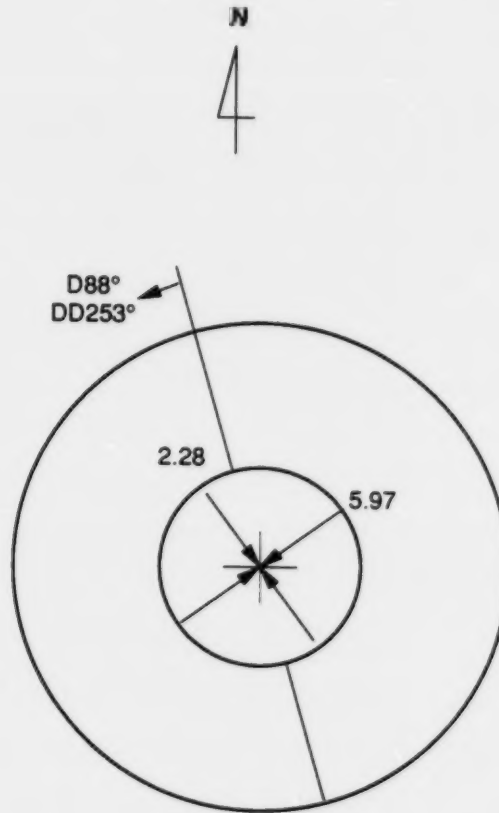


FIGURE 10

TEST 11
DEPTH 37.81 - 38.16 m
STRESS MAGNITUDES ARE IN MPa

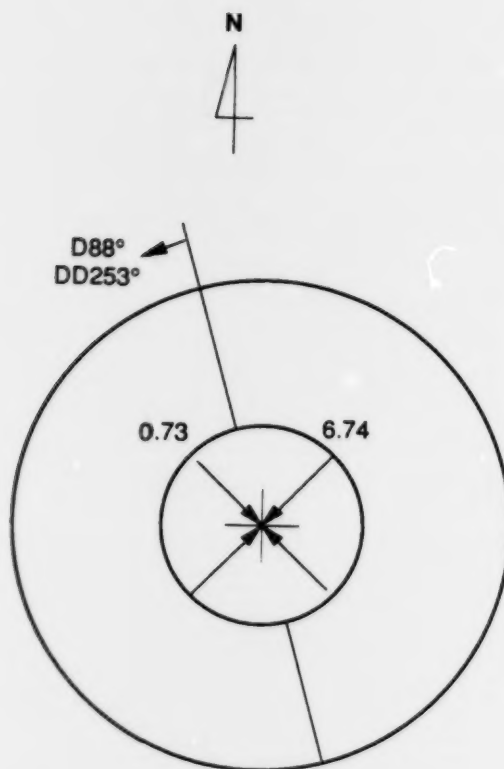


FIGURE 11
TEST 12
DEPTH 38.16 - 38.51 m
STRESS MAGNITUDES ARE IN MPa

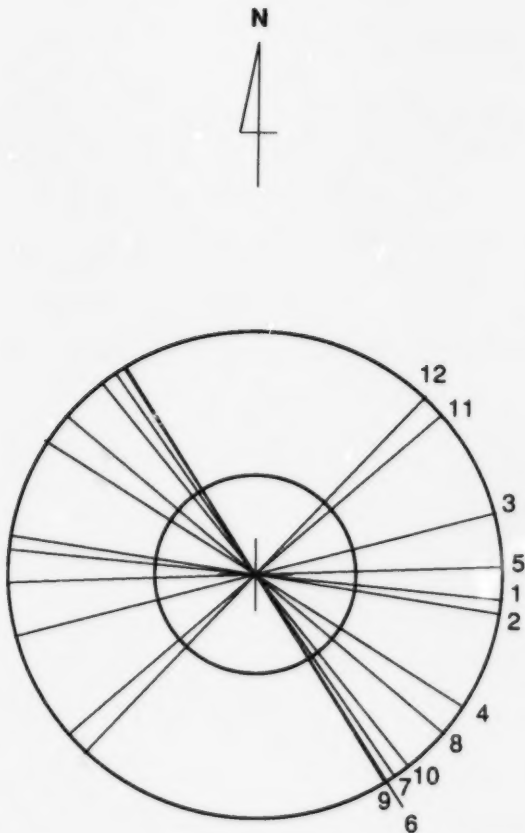
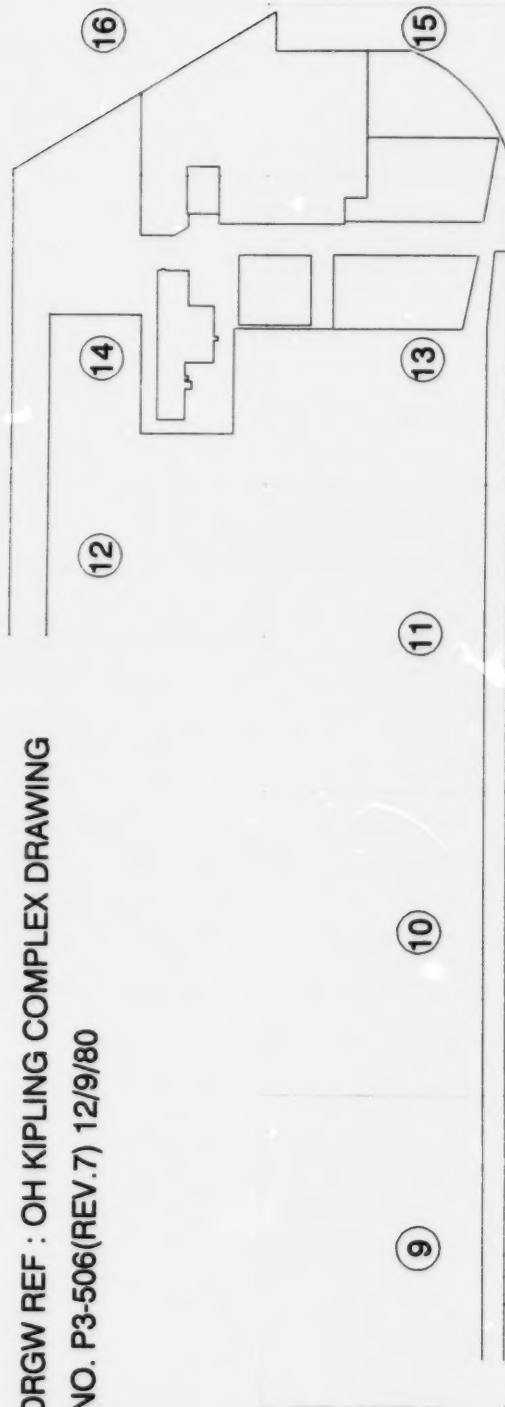


FIGURE 12
MAJOR SECONDARY PRINCIPAL (P)
STRESS ORIENTATIONS

LOCATION OF KJ AND KG BOREHOLES

DRGW REF : OH KIPLING COMPLEX DRAWING

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LEGEND

• BOREHOLE

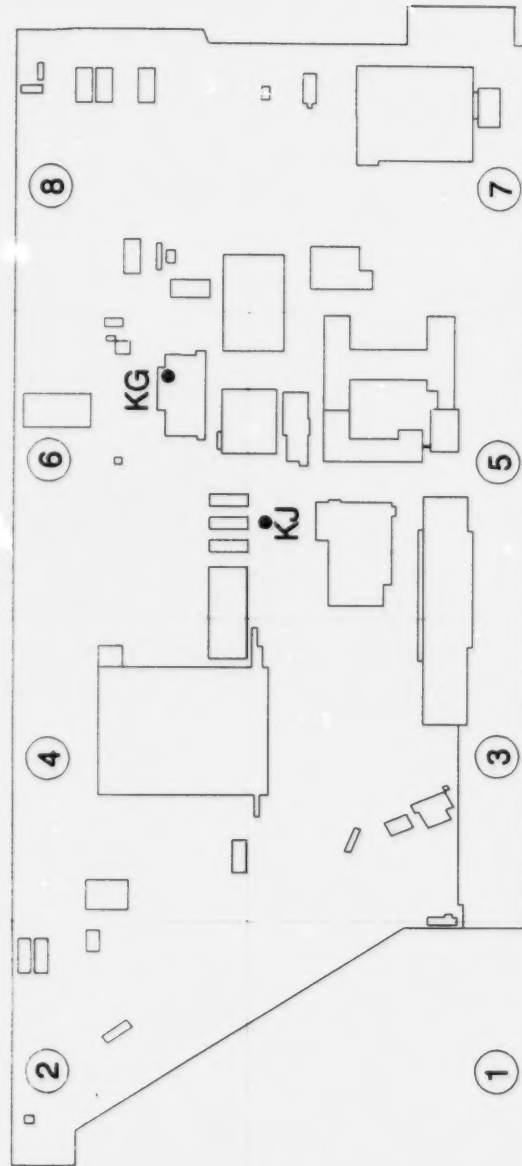


FIGURE 13

APPENDIX 1

**UNITED STATES BUREAU OF MINES
BOREHOLE DEFORMATION GAUGE
TEST METHOD**

THE UNITED STATES BUREAU OF MINES BOREHOLE DEFORMATION GAUGE TEST METHOD

The United States Bureau of Mines Borehole Deformation Gauge (USBM gauge) was chosen to measure the stresses existing in rock masses and concrete structures because past experience has shown it to be a reliable instrument. The method consists of drilling an HQ hole (diameter 97.5 mm), drilling a 10 cm long E pilot hole (diameter 38.1 mm), extending the E hole to approximately 60 cm in length, placing the USBM gauge into the hole and then overcoring the gauge with a thin wall bit. Strain readings are taken during this overcoring for each 13 mm of bit advance.

The accuracy for this test method claimed by the US Bureau of Mines is that the stresses measured are within 15% of actual stresses in concrete and slightly better in rock.

TEST THEORY

Strain relief measurements are made along three separate axes which form a 60° strain rosette. After the downhole testing is completed, the overcore is recovered and subjected to testing in a biaxial chamber to determine the Young's modulus of the material. This result is combined with the downhole strain relief measurements to calculate the secondary principal stresses existing in the plane perpendicular to the borehole axis. The maximum secondary principal stress (P) and the minimum secondary principal stress (Q) are termed secondary because they represent the maximum and minimum stress in one plane within a three dimensional rock mass. The relationship of P, Q and θ is shown in Figure 1. Three non-parallel boreholes would be required to completely define the three dimensional stress field using this test method.

The analytical method used to calculate the stresses is based on elastic thick wall cylinder theory using a 60° strain rosette solution. The equations used are:

$$P = \frac{E}{(1-\nu^2)d} \left[U_1 + U_2 + U_3 + \frac{1}{\sqrt{2}} \left[(U_1 - U_2)^2 + (U_2 - U_3)^2 + (U_3 - U_1)^2 \right]^{1/2} \right]$$

$$Q = \frac{E}{(1-\nu^2)d} \left[U_1 + U_2 + U_3 - \frac{1}{\sqrt{2}} \left[(U_1 - U_2)^2 + (U_2 - U_3)^2 + (U_3 - U_1)^2 \right]^{1/2} \right]$$

$$\theta = \frac{1}{2} \tan^{-1} \frac{\sqrt{3} (U_2 - U_3)}{2U_1 - U_2 - U_3}$$

where P is the major secondary principal stress
 Q is the minor secondary principal stress
 θ is the angle measured from gauge axis U_1 to P in a counter-clockwise direction
 E is the Young's Modulus of elasticity of the rock in which the measurement was made (Note: refer to Biaxial Testing Section for a description of this test method)
 ν is the Poisson's ratio of the rock
 d is the diameter of the borehole in which the gauge was placed
 U_1, U_2, U_3 - are the strains measured along the three gauge axes and are positive for an increasing diameter

Deformation Curves

Prior to the computation of the stresses, the test data is plotted to ensure that no unusual downhole behaviour such as drill vibration is misinterpreted as actual strain relief. An example of these curves which plot deformation versus the depth of bit is given in Figure 2.

GAUGE PLACEMENT AND ORIENTATION

The placement of the gauge is accomplished by means of a series of keyed aluminum rods that attach to a placing tool (Figure 3). The gauge is fastened to the placing tool and lowered into the HQ hole until just above the E hole. Prior to the placement of the gauge the wall of the E pilot is scribed using the scribing tool shown in Figure 4. The hardened steel point is aligned with a scope mounted on top of the rods before it is pushed into the hole as shown in Figure 4. The mark enables proper orientation of the gauge in the core during the biaxial test to determine the Young's Modulus of Elasticity of the core in the same directions as the downhole strain readings were made. The scope, as shown in Figure 5, is used to sight a predetermined reference point so that the azimuth of P can be calculated. The gauge is aligned in the same manner.

Drilling Procedure

The drilling procedure for this test makes use of a modified wire line system that was developed by Longyear Canada during several projects at or near the Darlington NGS site. A crawler mounted CME drill equipped with a hydraulic chuck is used as this requires a drill set up time of less than one half day. The hydraulic chuck enables the rods to be easily centered in the hole each time. The drill set up is shown in Figure 6.

The procedure used in preparing the hole for an overcore test is outlined below. The sequence of operations is shown in Figure 7.

1) The hole is advanced to a depth that is 20cm above the predetermined test depth by normal wire line drilling practice using an HQ bit.

2) The HQ standard HQ inner barrel assembly is removed and replaced by a modified assembly that is shown in Figures 8-11. The barrel does not rotate and enables this barrel to be used to drill the E hole.

3) A 10 cm (4 in) E starter barrel is attached to the inner tube and lowered into the hole. A 10 cm starter hole is drilled after the H rods are pulled back approximately 15 cm to ensure the core barrel dogs are engaged.

4) The inner barrel assembly is removed and the starter barrel is replaced by a 60 cm E core barrel. After encountering difficulty in obtaining E core that indicated natural discontinuities and breaks in the rock as opposed to breaks that are caused by drilling, it was decided to switch from a single barrel E core to an IEWS barrel that is shown in Figures 10 and 11. The IEWS barrel has an inner tube that is free to swivel and greatly reduces core breakage due to vibration during drilling and enabled a truer estimation of rock conditions to be made. This improvement enables the avoidance of zones of poor rock which would have jeopardized the gauge with a core breakage during the test. In this step, as in step 3, the H rods are raised to engage the dogs on the core barrel to enable drilling of the E hole.

5) The E core is carefully inspected to ensure that it is possible to carry out a test. It is necessary to have at least 20 cm of solid rock below the buttons. These lengths of rock are necessary to ensure that the complete stress relief action of the core can be monitored during the test.

6) The HQ rods are pulled and the HQ bit is replaced by the thin wall industrial core bit.

7) The E hole is scribed with the scribe shown in Figure 4.

8) The gauge is lowered through the water swivel and drive rod, then attached to the placement tool, lowered down the hole, oriented and then pushed into the E hole.

9) The end plug, through which the electrical readout cable is run, is screwed into the water swivel. The readout cable is then connected to the Vishay strainmeters.

10) The gauge is allowed to thermally stabilize in the E hole for five minutes.

11) The drill water pressure and drill speed are adjusted.

- 12) The overcoring begins with strain readings taken for every 1.27 cm (0.5 in) of bit advance.
- 13) At the completion of the overcoring the gauge is removed.
- 14) The H rods are pulled from the hole and the core breaker is lowered down the hole.
- 15) The core breaker is removed from the hole and the core catcher is lowered to retrieve the core.
- 16) The overcore is removed and prepared for biaxial testing.
- 17) The HQ bit and rods are lowered down the hole and the hole is extended down to the next test horizon.

Biaxial Testing

After completion of the down hole overcoring, the core is prepared for testing in the biaxial chamber. The chamber which is shown in Figure 12 consists of a hollow aluminum cylinder lined with a rubber membrane. A known hydraulic pressure is applied with a hand operated hydraulic pump. The pressure in the system is monitored by means of a gauge attached to the pump.

Once the core has been placed into the chamber and the gauge is inserted into the overcore using the scribe mark as an orientation guide, the system is bled of air bubbles. The core is cycled three times and the strains measured by the gauge monitored on the Vishay readouts. This enables the value of Young's modulus of the core to be determined.

The Young's Modulus of Elasticity (E) is calculated using the formula:

$$E = \frac{4ab^2P_s}{(b^2-a^2)U}$$

where a = inner radius of overcore
 b = outer radius of overcore
 P_s = applied hydraulic pressure
 U = diametral borehole deformation

When the overcore is tested, the E value is determined along each of the three axes and if it is found that the three values E₁, E₂ and E₃ vary by more than 25%, then it is necessary to apply an anisotropic solution to the field test data.

Only two anisotropic elastic constants of the material are necessary for the plane strain evaluation of secondary stresses (Hooker & Johnson, 1969). These parameters are:

$$\alpha_{11} = \frac{1 - \gamma_{13} \gamma_{31}}{E_1}$$

$$\alpha_{22} = \frac{1 - \gamma_{23} \gamma_{32}}{E_2}$$

where E_i = Young's modulus in the i direction
 γ_{ij} = Poisson's ratio in the ij plane

The above subscripts refer to the orthogonal coordinate system defined by the axis of the core and the directions of maximum and minimum Young's modulus in the plane perpendicular to the axis of the core. This procedure avoids errors in the field data that are due to elastic non-linearity in the rock. This method involves many calculations and subsequent laboratory tests. Tullis (1981) found that, by using what he termed an "approximate" anisotropic solution, it was possible to obtain results that varied little from the Hooker and Johnson (1969) solution and yet avoided the cumbersome analysis and testing. This method was applied to all of the tests results to correct for the effect of rock anisotropy. The equation is:

where $U_i^m = U_i(E_i/E)$ $i = 1, 2, 3$
 E_i = is Young's modulus for each axis
 E = is the average Young's modulus for the three axes
 U_i = is the deformation for measured on axis i
 U_i^m = is the modified deformation on axis i

The modified deformations are then substituted into the original equations, (1), (2) and (3), for P, Q and θ and new values of P, Q and θ are calculated. The results of the biaxial tests are plotted as load versus deformation such as those shown in Figure 13, to ensure that the rock material is behaving elastically. Readings are taken during the loading and unloading portion of each of the three load-unload cycles. The unloading cycle E value is used in stress calculations because this simulates the downhole stress relief of the rock core as it is overcored.

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2. Tullis, T.E. "Stress Measurements Via Shallow Overcoring Near the San Andreas Fault" in "The Mechanical Behaviour of Crustal Rocks, The Handin Volume", Geophysical Monograph 24, American Geophysical Union, 1981.

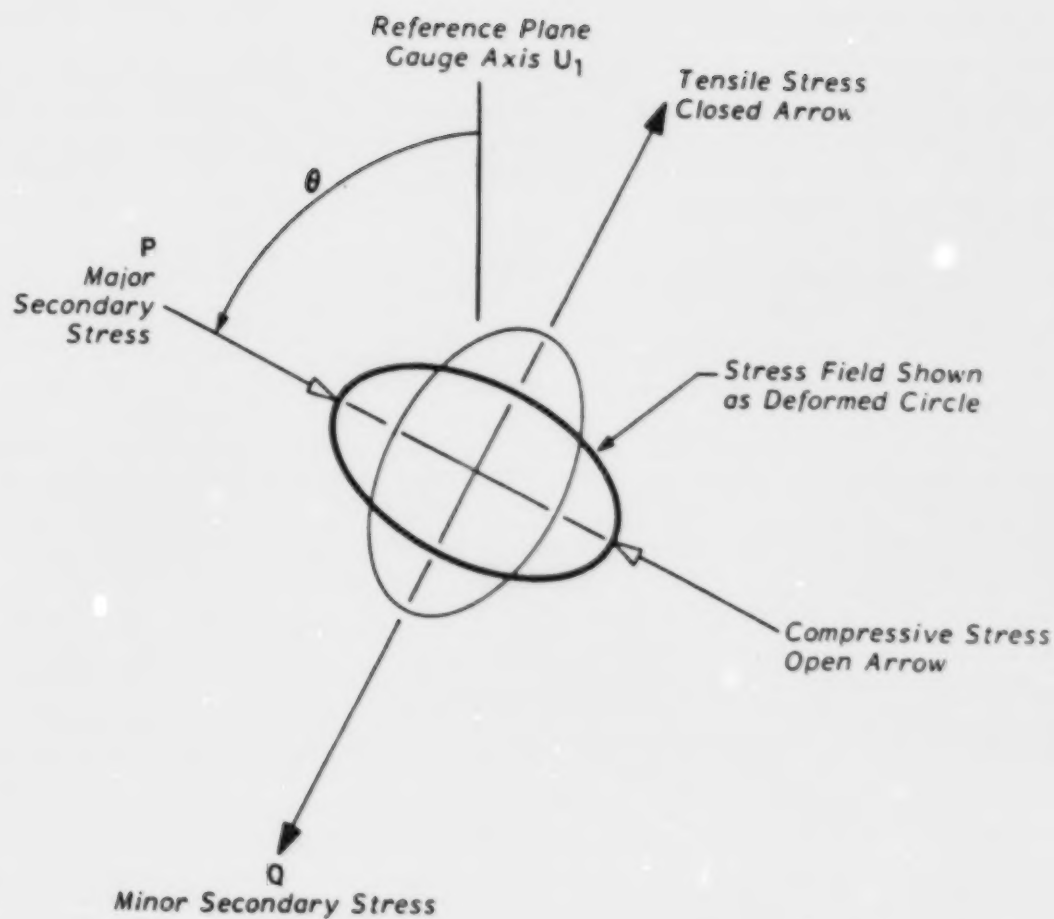


FIGURE 1
IN SITU STRESS TERMINOLOGY

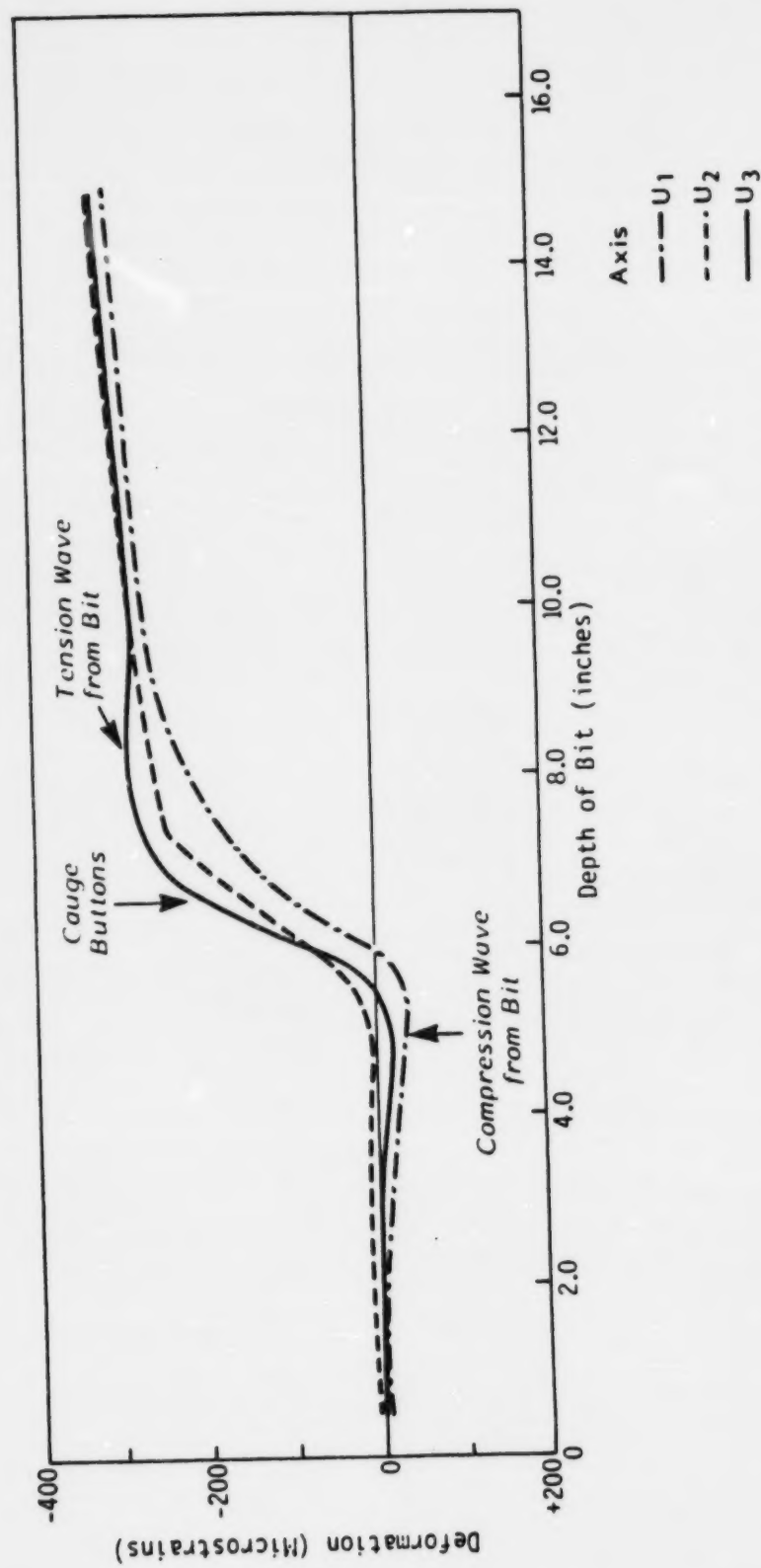


FIGURE 2
TYPICAL DEFORMATION CURVES FROM OVERCORING TEST



FIGURE 3
PLACING TOOL FOR USBM GAUGE

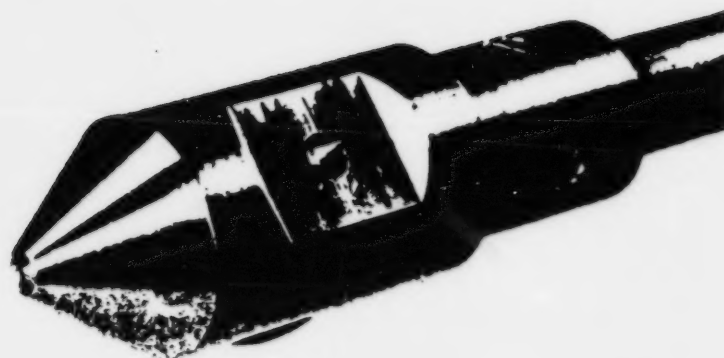


FIGURE 4
STEEL SCRIBING POINT

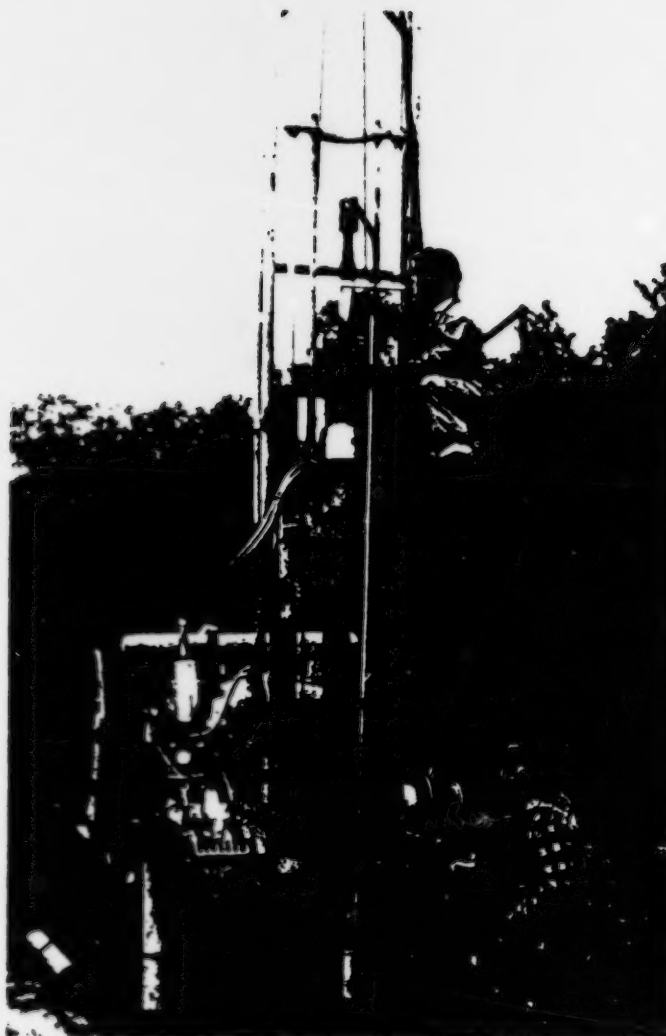


FIGURE 5
ORIENTATION OF THE GAUGE



FIGURE 6
DRILL RIG SET UP FOR OVERCORING

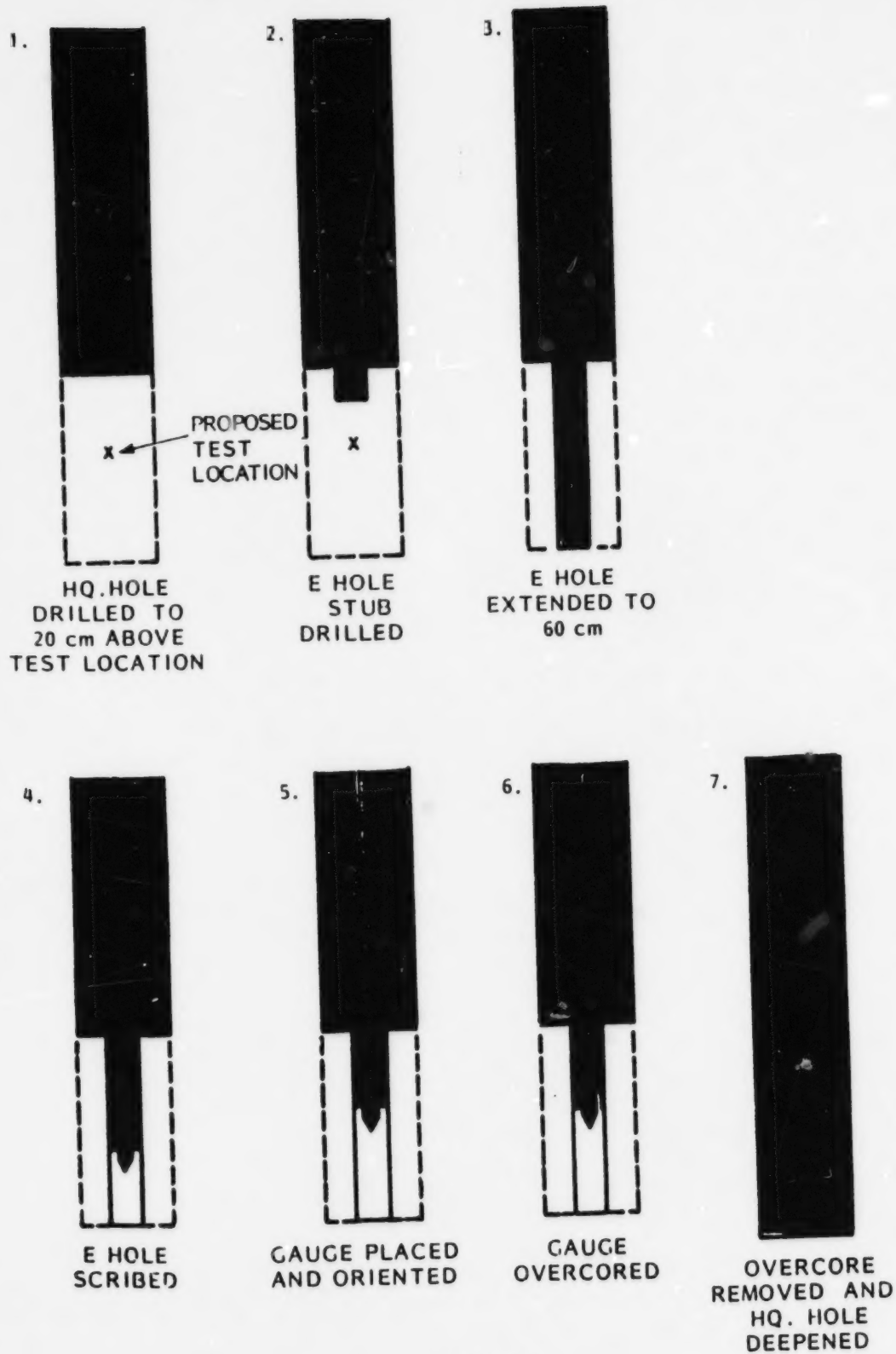


FIGURE 7
SEQUENCE FOR OVERCORE TEST
USING HQ. WIRELINE SYSTEM



FIGURE 8

TOP STANDARD INNER BARREL ASSEMBLY
 BOTTOM MODIFIED INNER BARREL ASSEMBLY



FIGURE 9

LOWER END OF MODIFIED INNER
 BARREL ASSEMBLY WITH E BARREL
 ADAPTOR IN PLACE

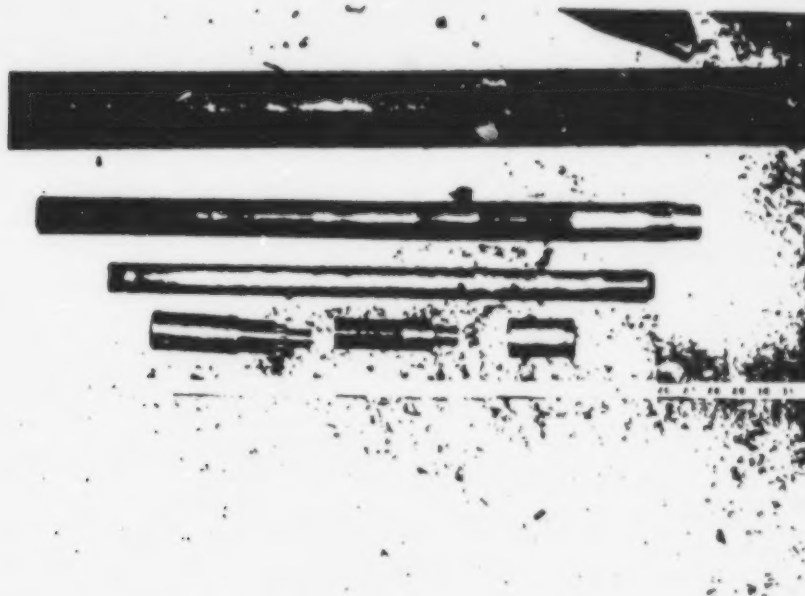


FIGURE 10

DISASSEMBLED IEWS CORE BARREL



FIGURE 11

ASSEMBLED IEWS CORE BARREL

154430 RD

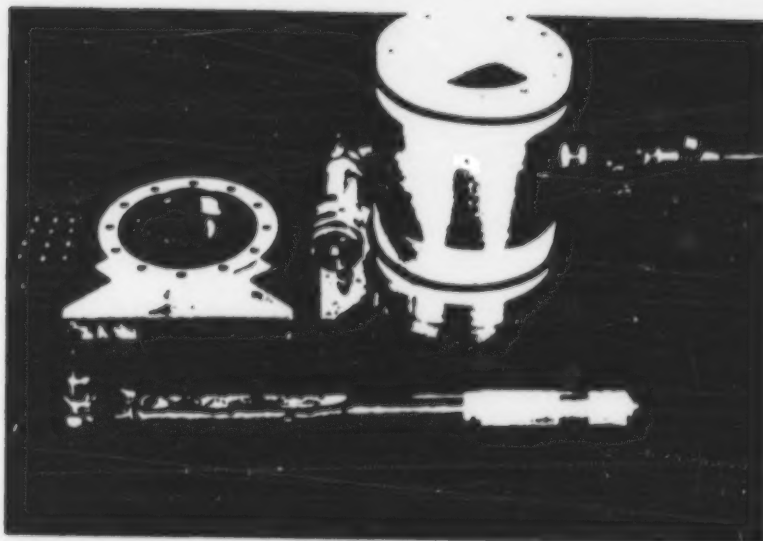


FIGURE 12
BIAXIAL CELL FOR YOUNG'S MODULUS DETERMINATION

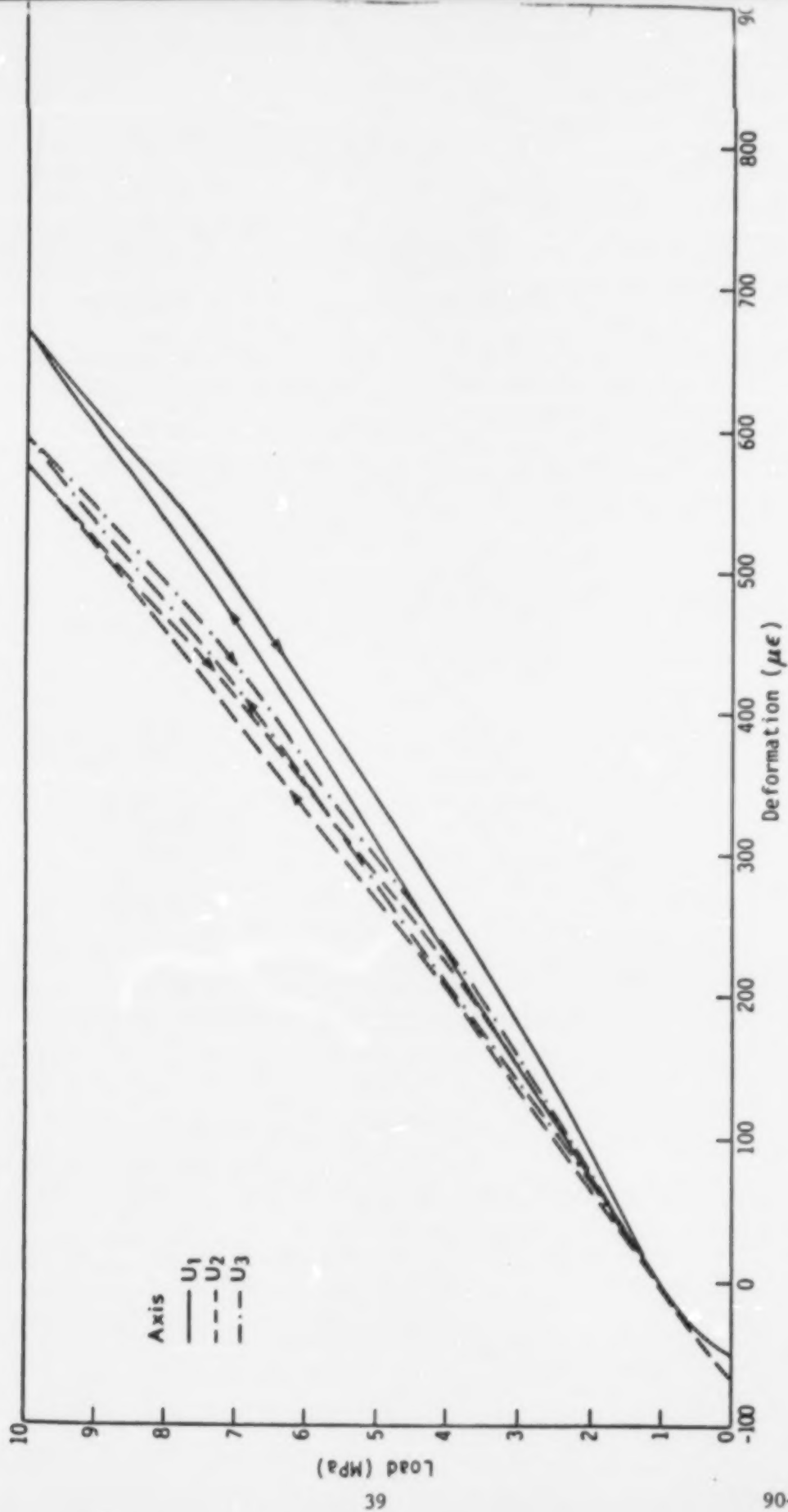
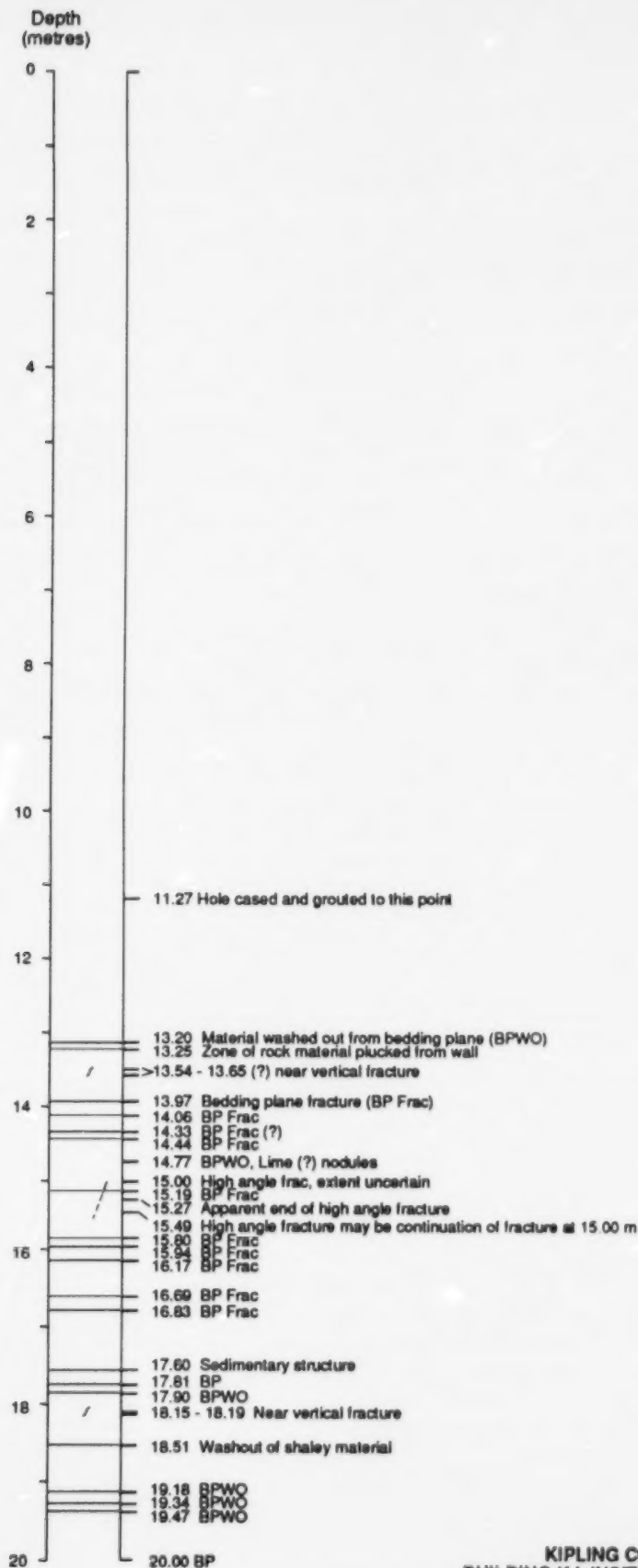


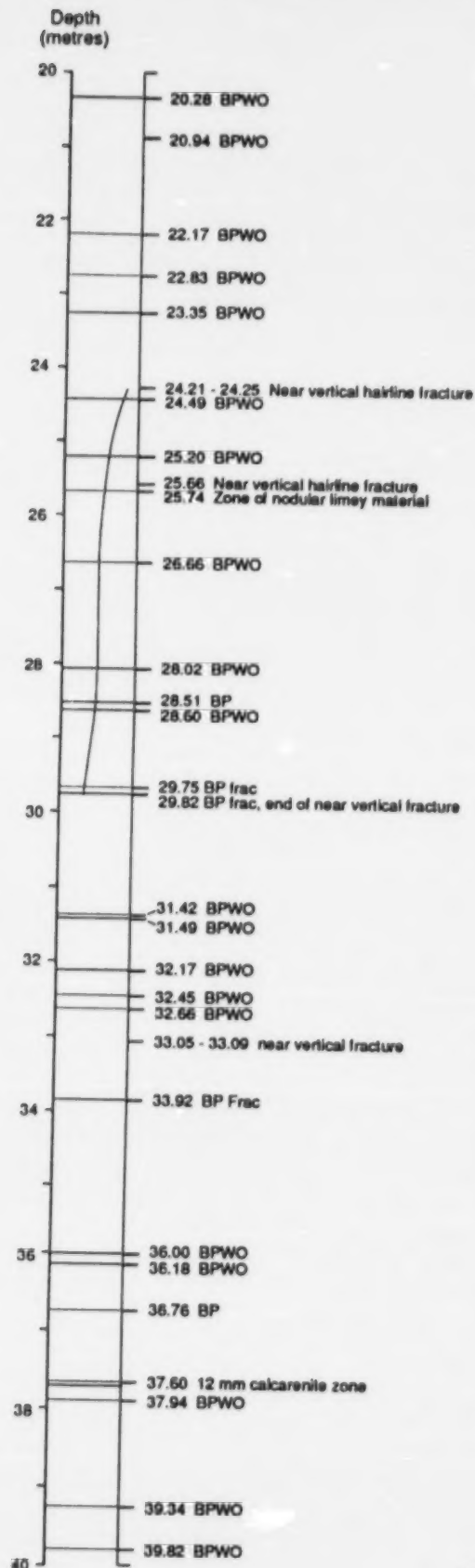
FIGURE 13
TYPICAL BIAxIAL TEST RESULTS

APPENDIX 2

BOREHOLE CAMERA LOG



KIPLING COMPLEX
 BUILDING KJ, INSITU STRESS STUDY
 BOREHOLE CAMERA SURVEY
 NOV. 22, 1989
 DIP: -90°
 COLLAR ELEV. : ± 115.53 m



KIPLING COMPLEX (cont'd)
 BUILDING KJ, INSITU STRESS STUDY
 BOREHOLE CAMERA SURVEY
 NOV. 22, 1989
 DIP: -90°
 COLLAR ELEV. : ± 115.53 m

Depth
(metres)

40

42

42.82 BP
42.89 END OF BOREHOLE

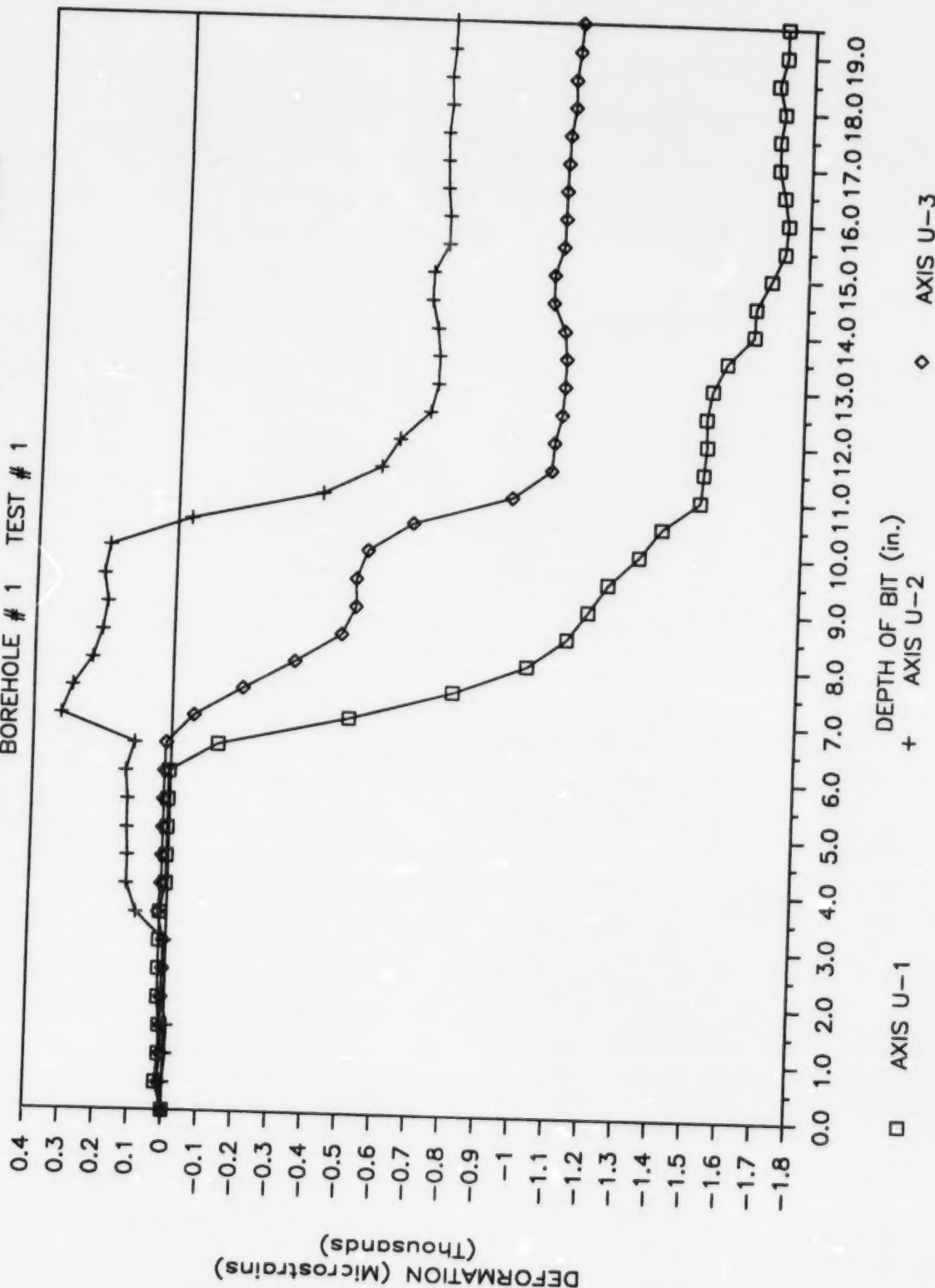
Page 3 of 3

KIPLING COMPLEX (cont'd)
BUILDING KJ, INSITU STRESS STUDY
BOREHOLE CAMERA SURVEY
NOV. 22, 1989
DIP: -90°
COLLAR ELEV. : ± 115.53 m

APPENDIX 3
OVERCORING TEST FIELD CURVES

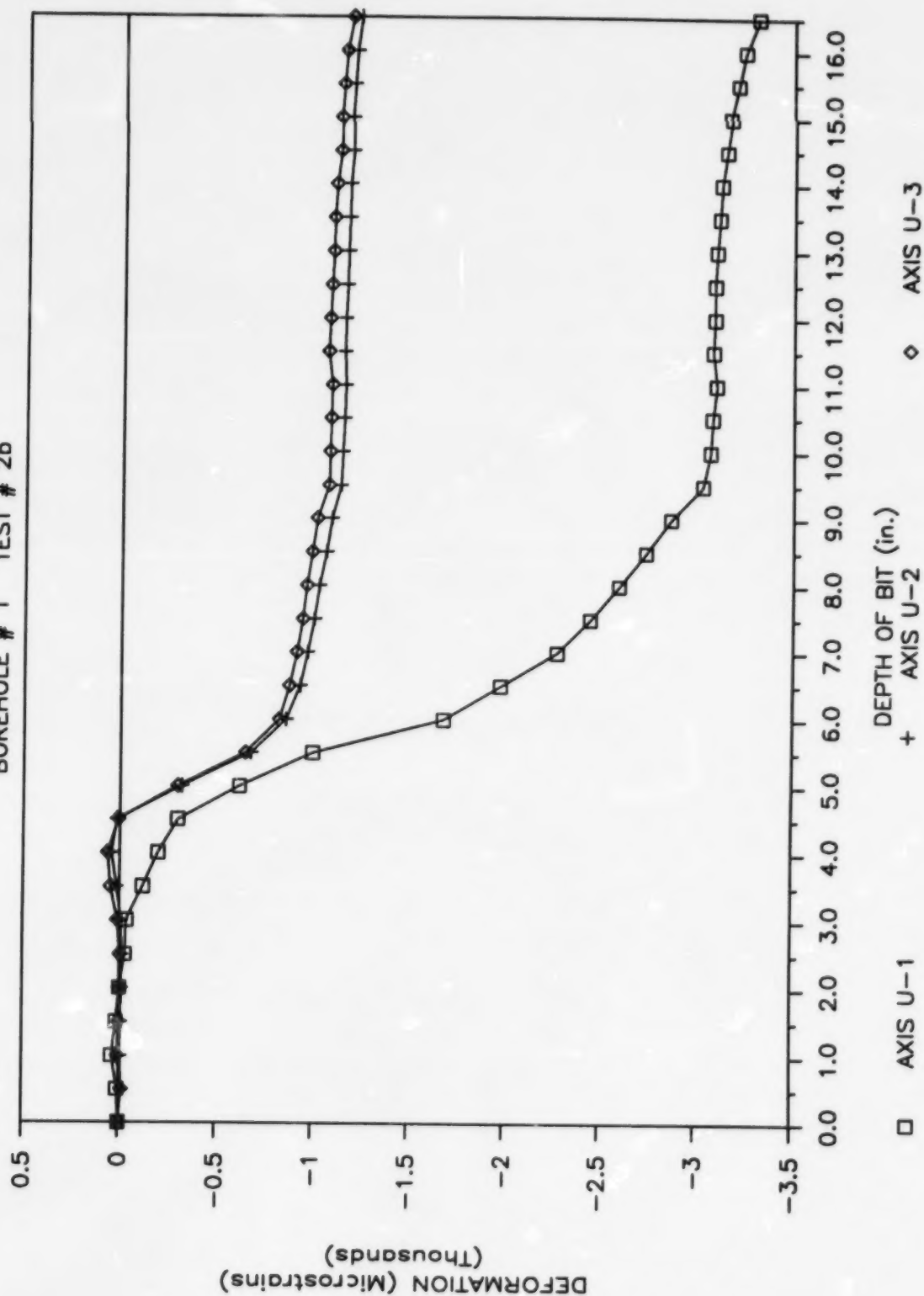
KIPLING COMPLEX BLDG KJ NOV. 1989

BOREHOLE # 1 TEST # 1



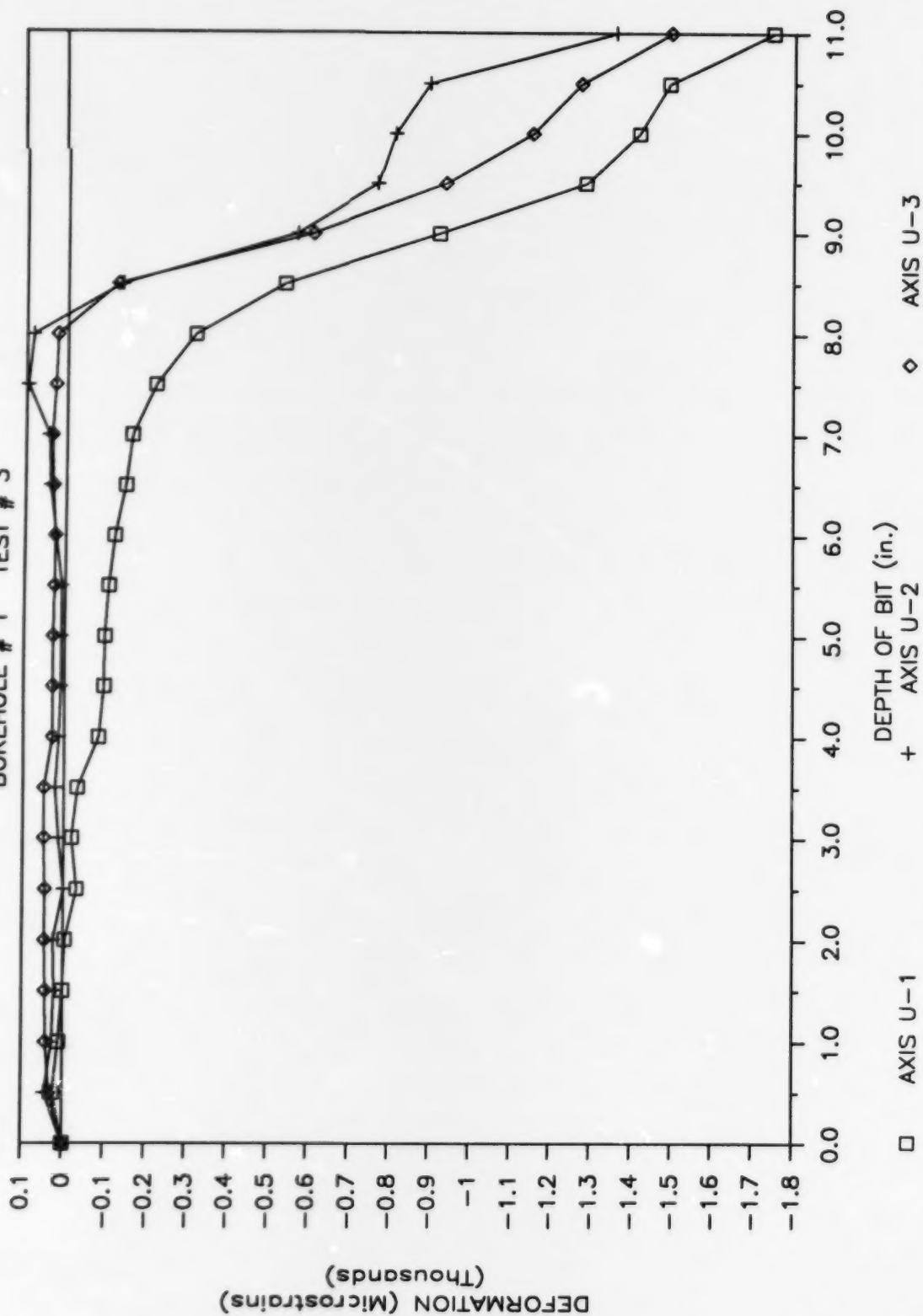
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 2b



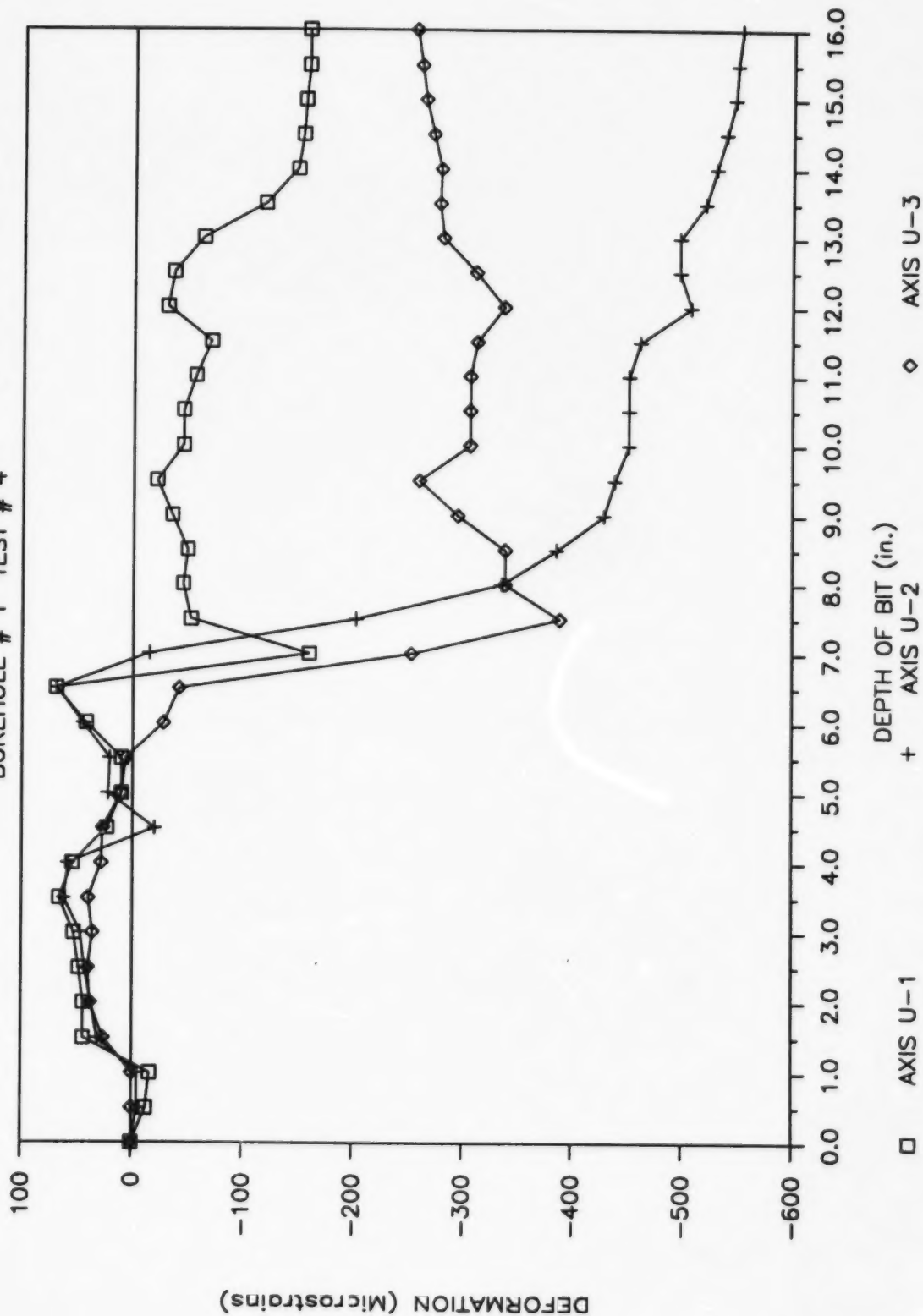
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 3



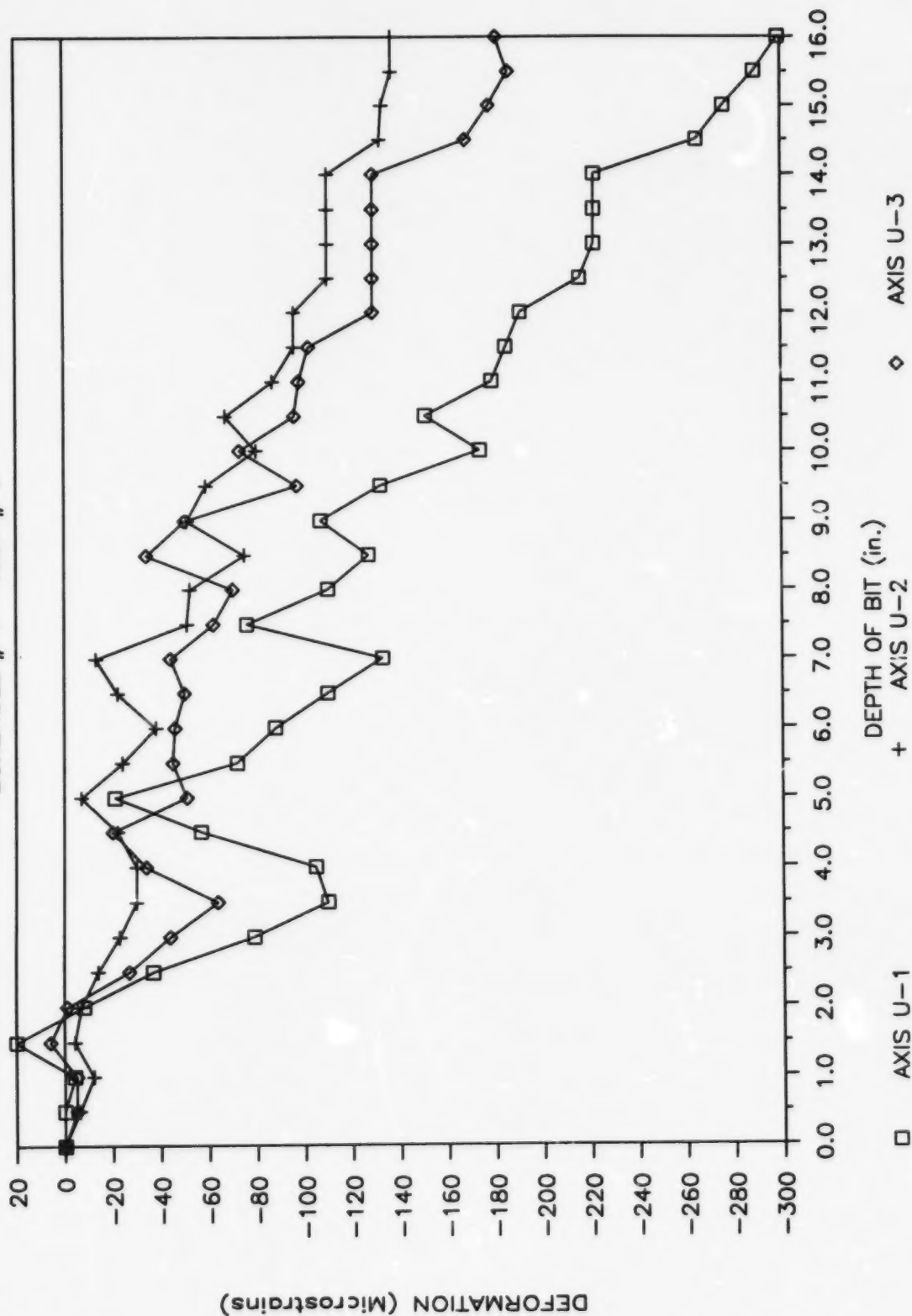
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 4



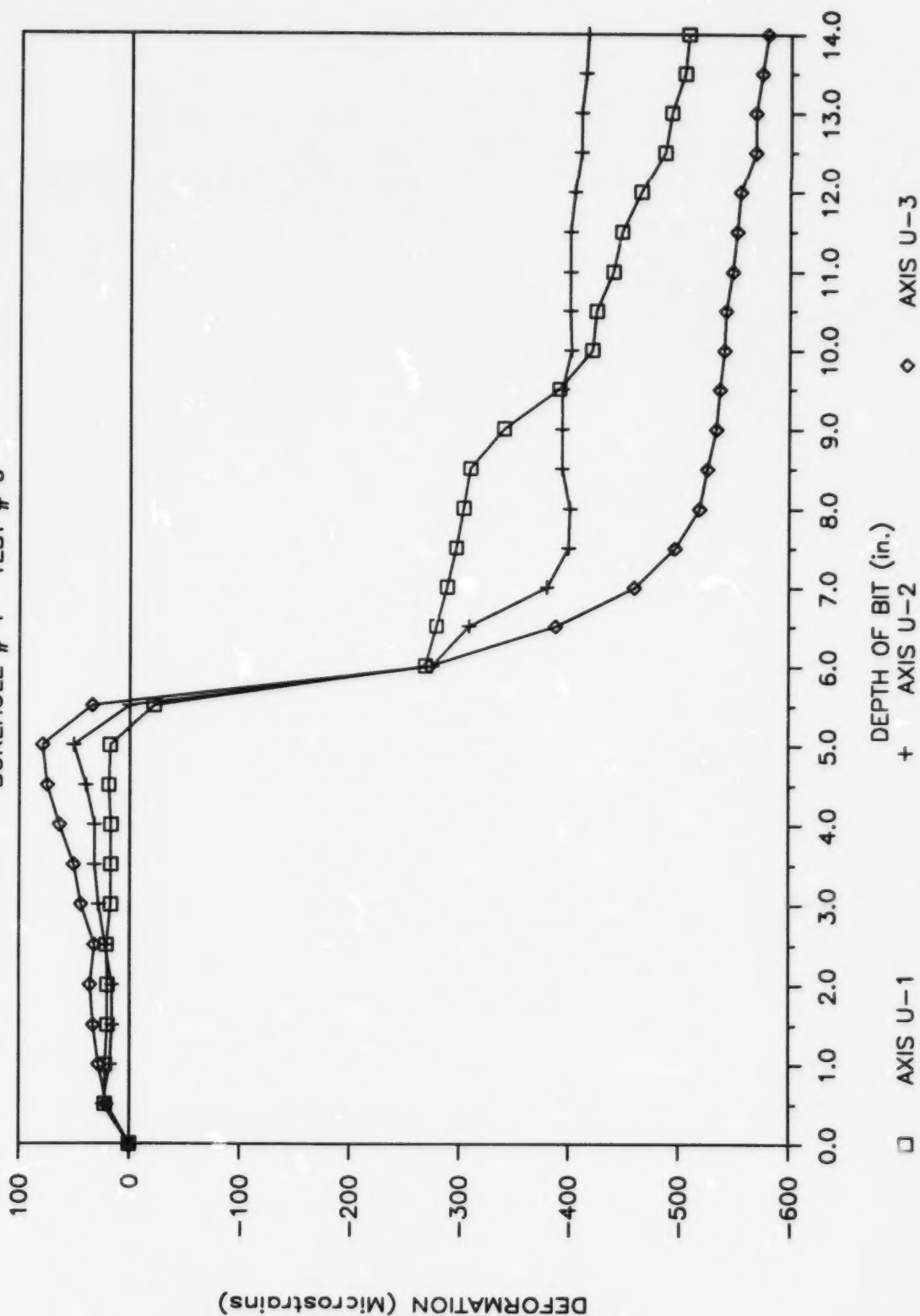
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 5



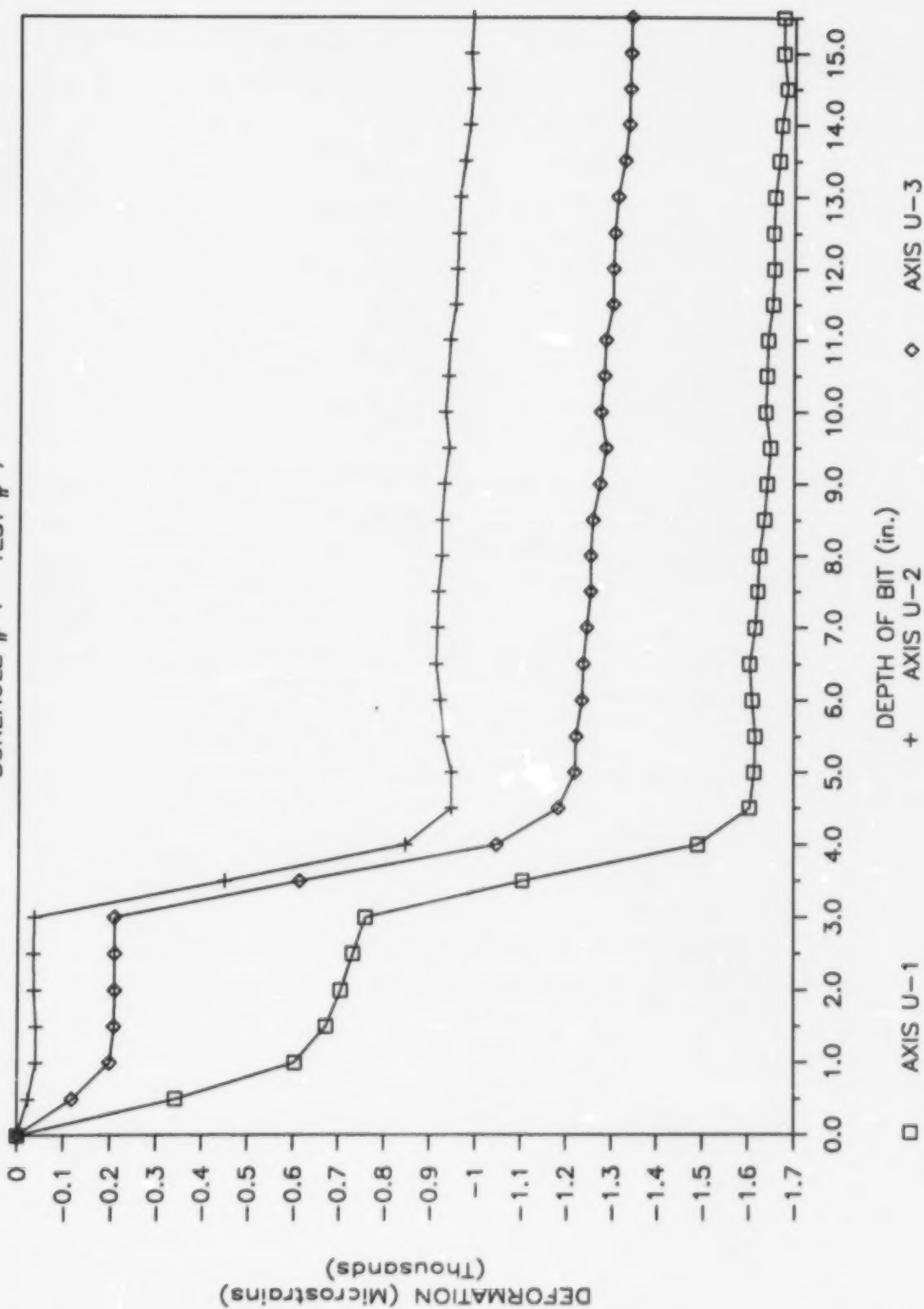
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 6



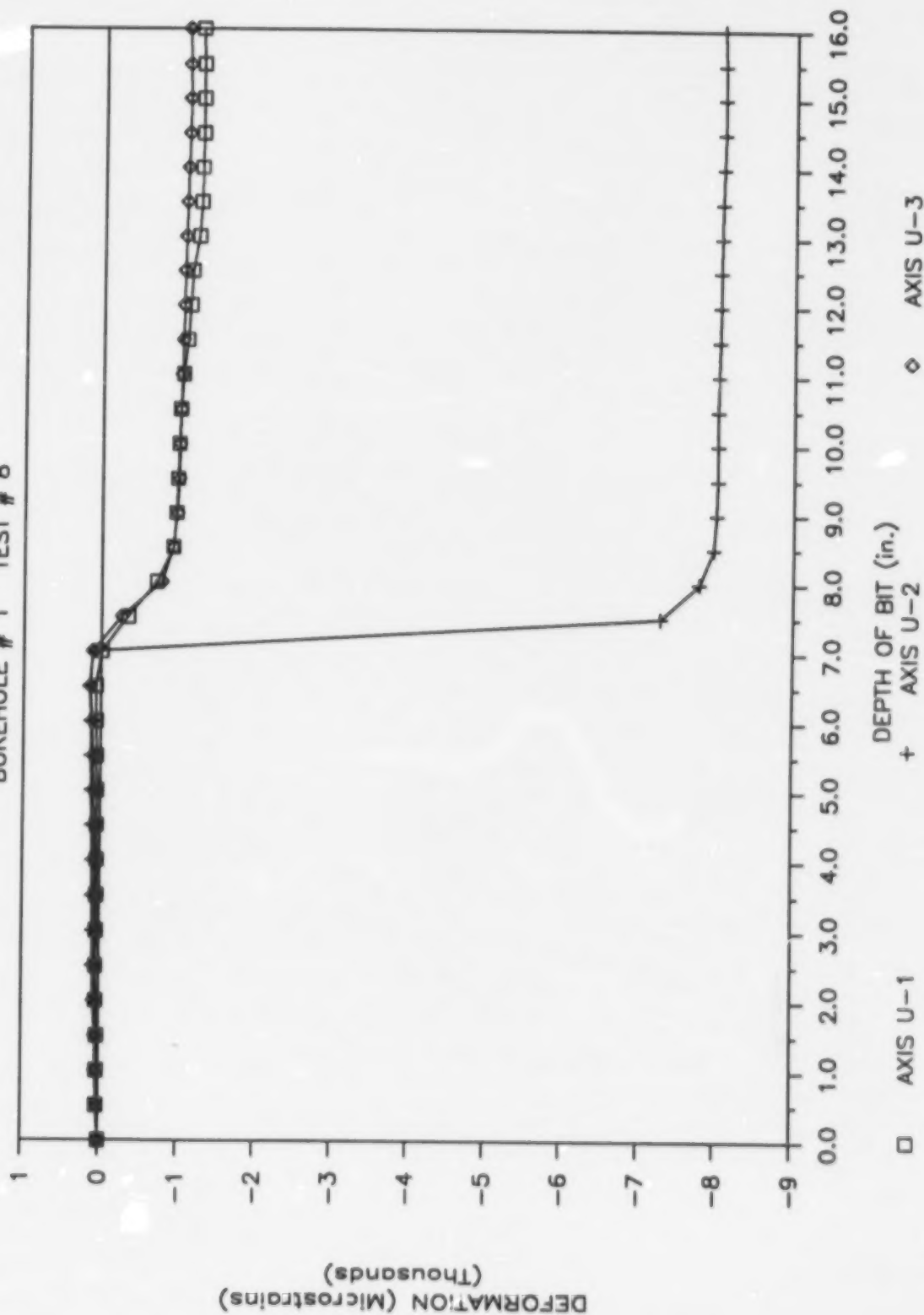
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 7



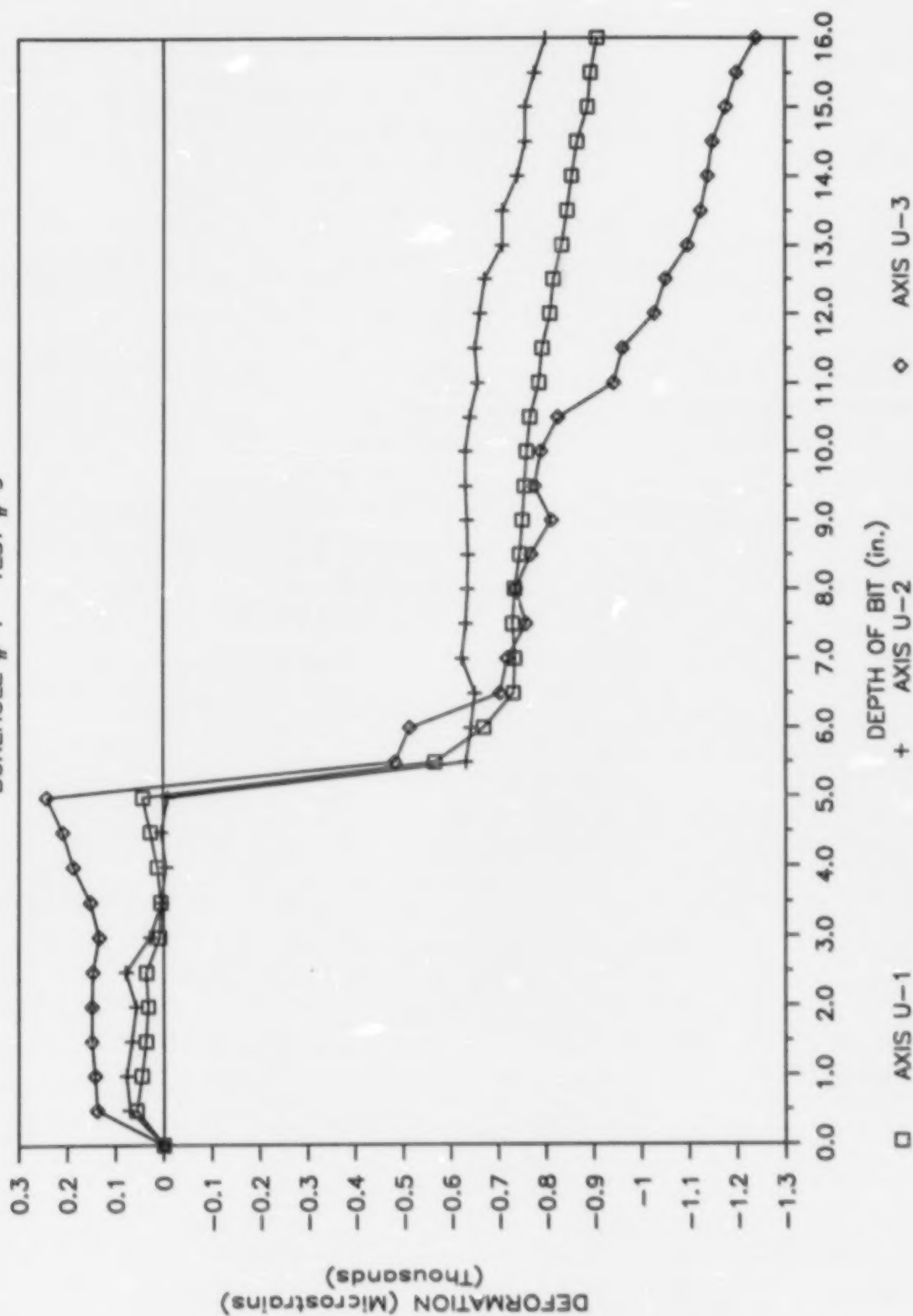
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 8



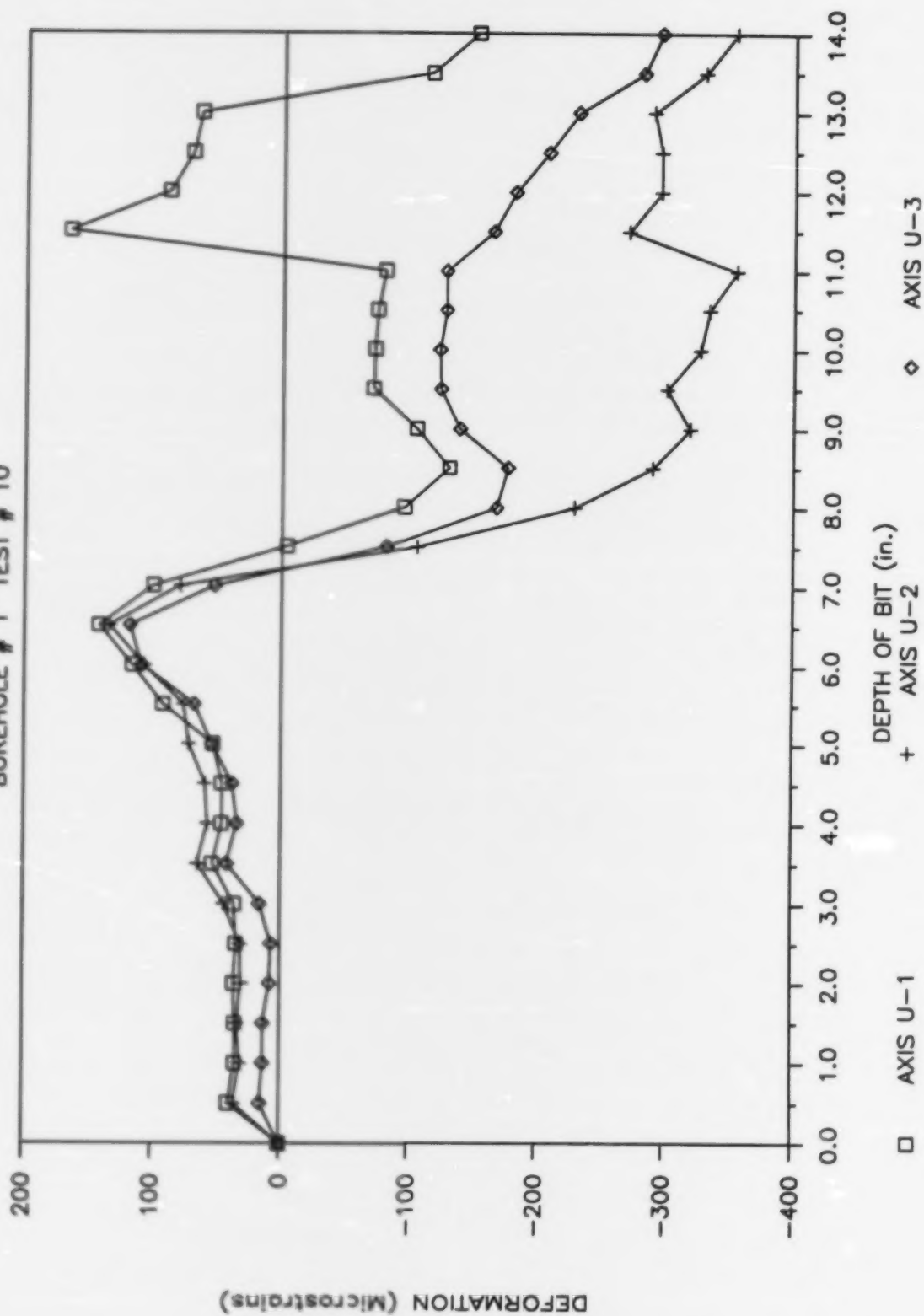
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 9



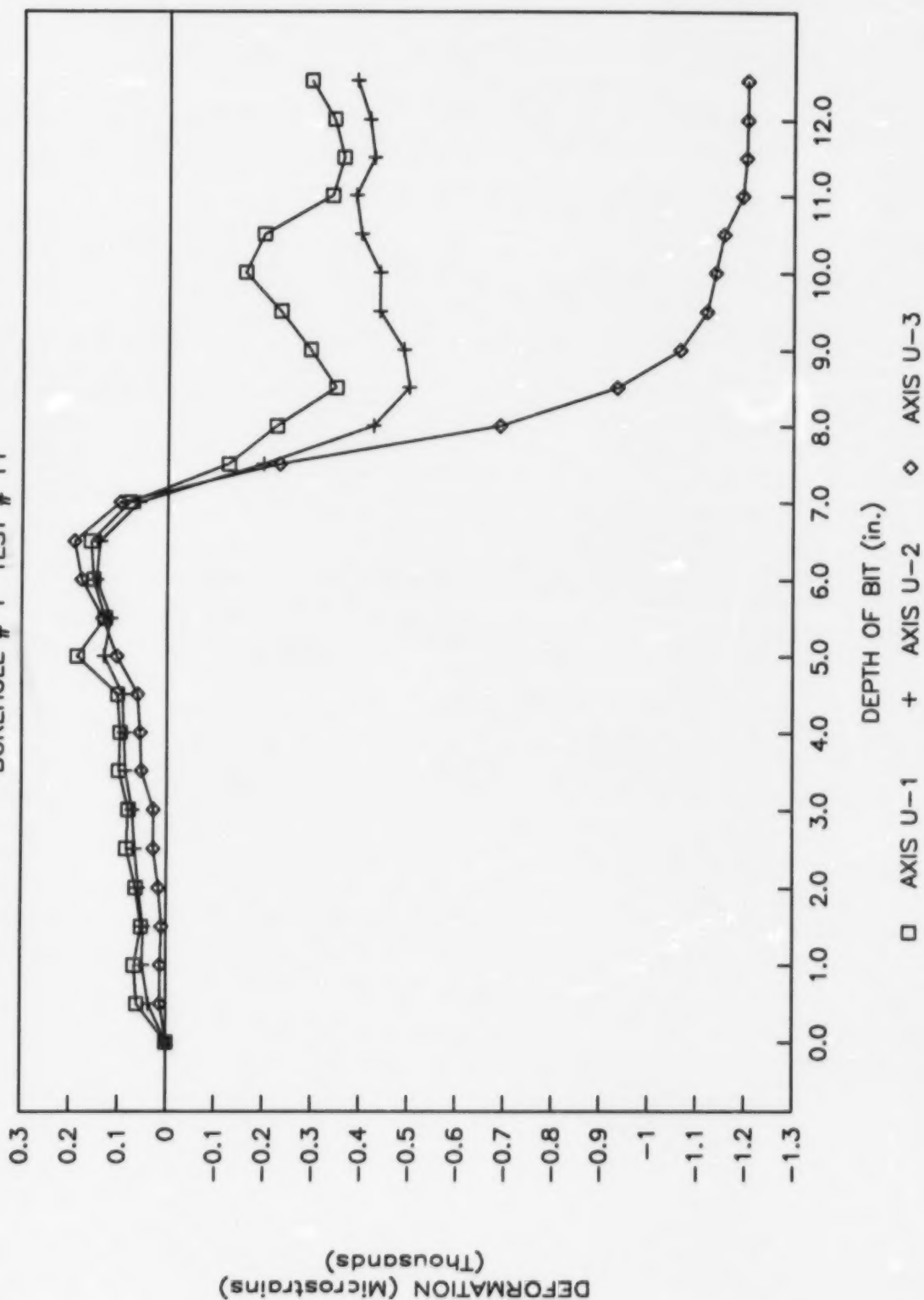
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 10



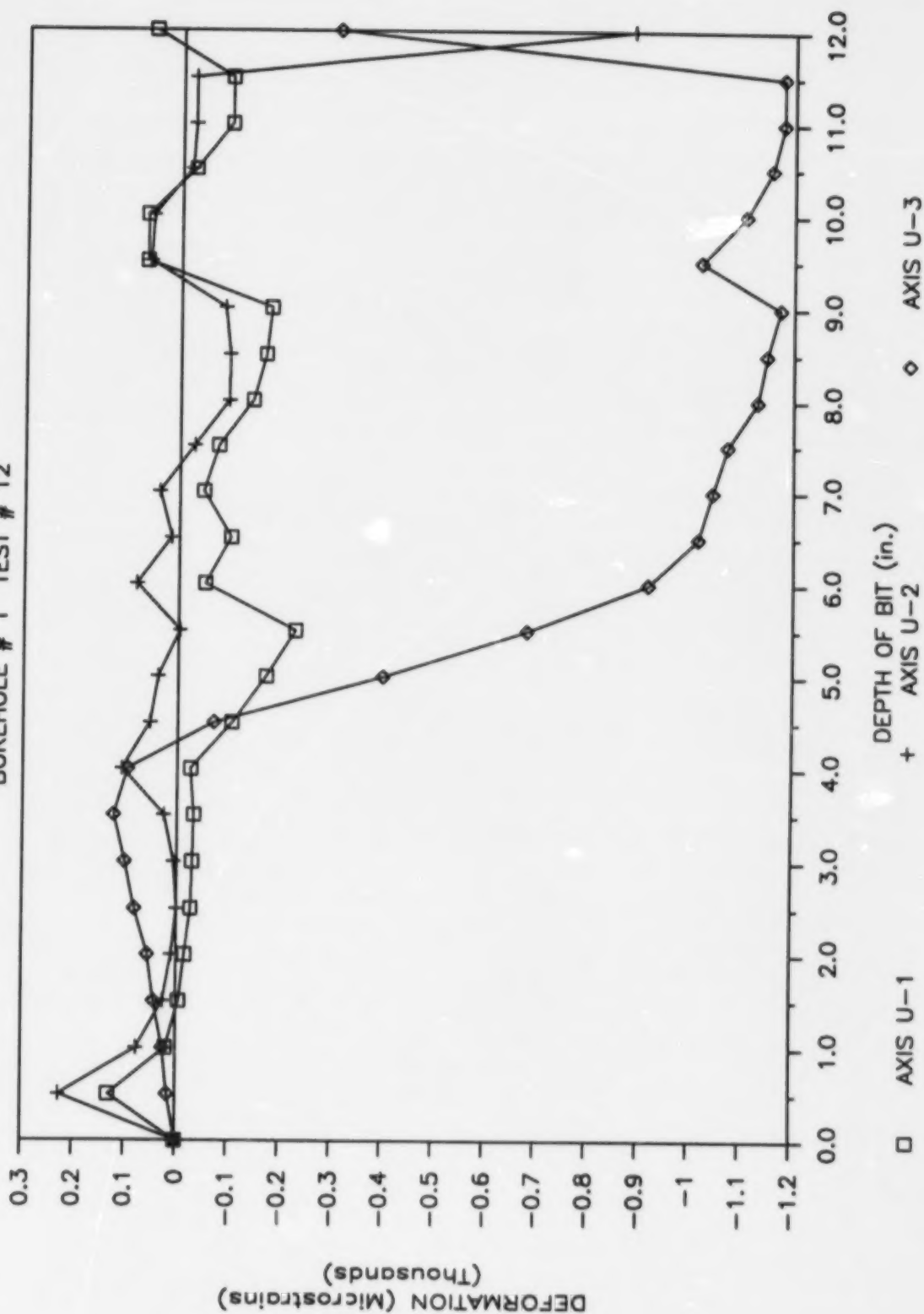
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 11



KIPLING COMPLEX BLDG KJ NOV.1989

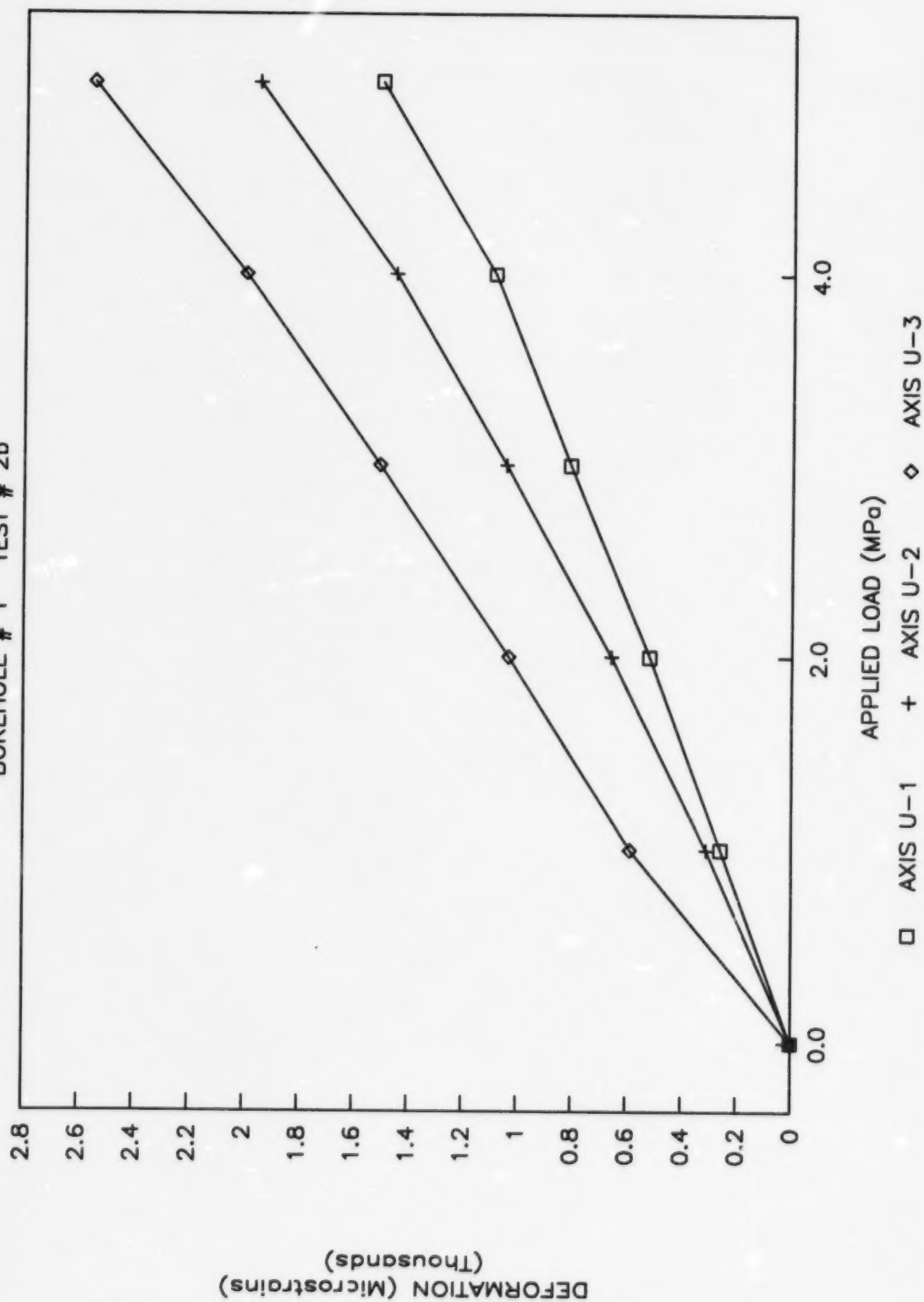
BOREHOLE # 1 TEST # 12



APPENDIX 4
BIAXIAL TEST CURVES

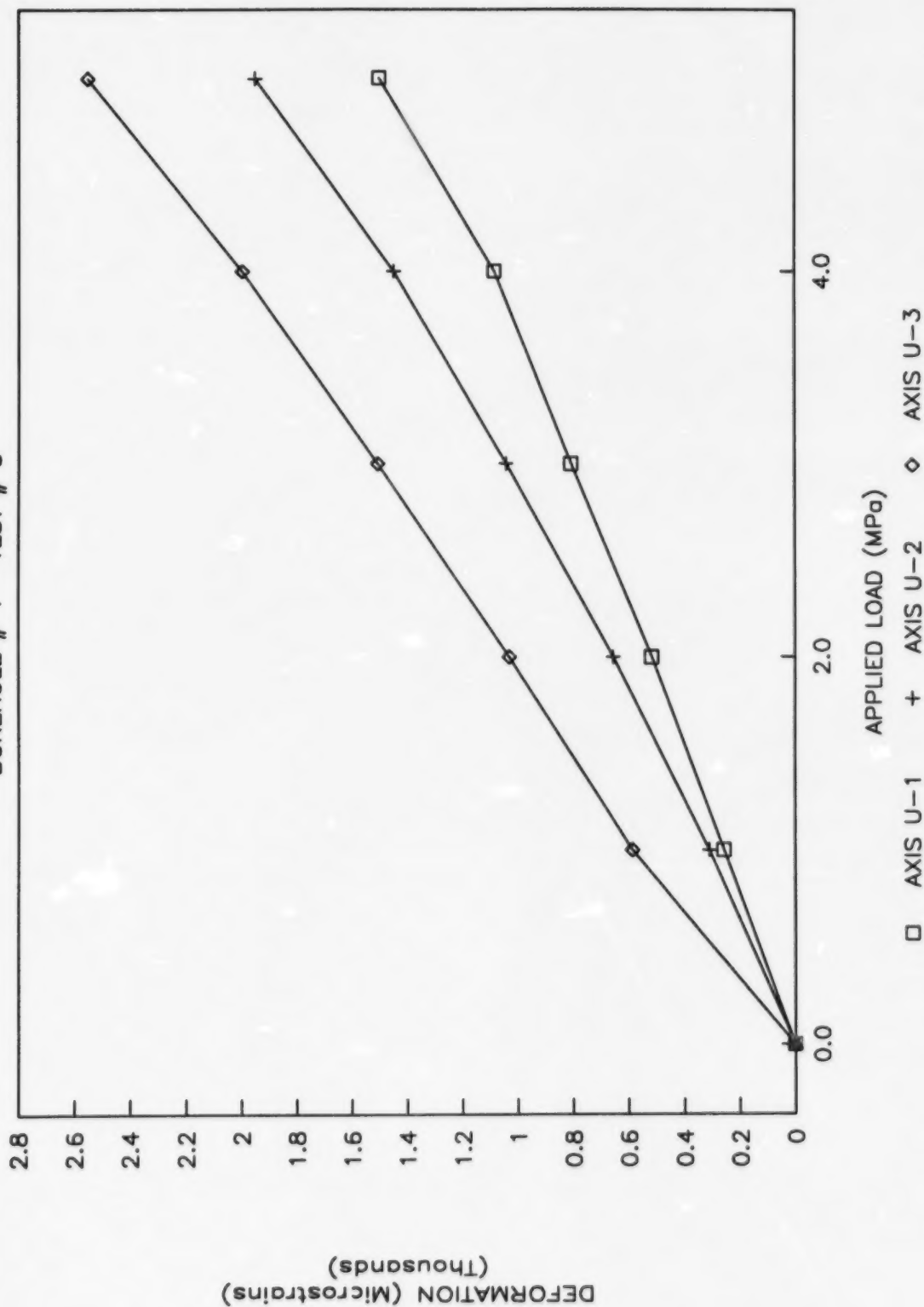
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 2b



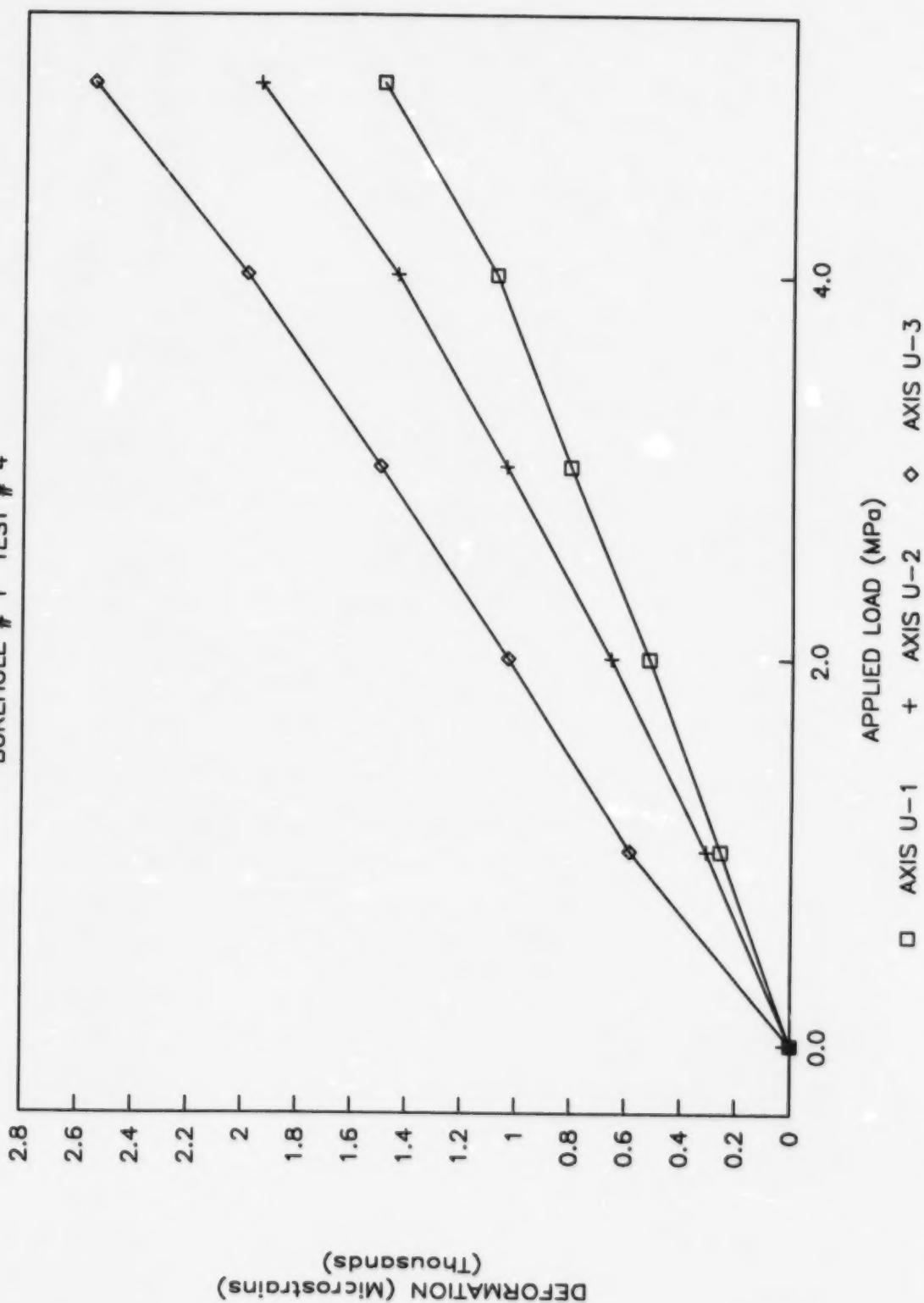
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 3



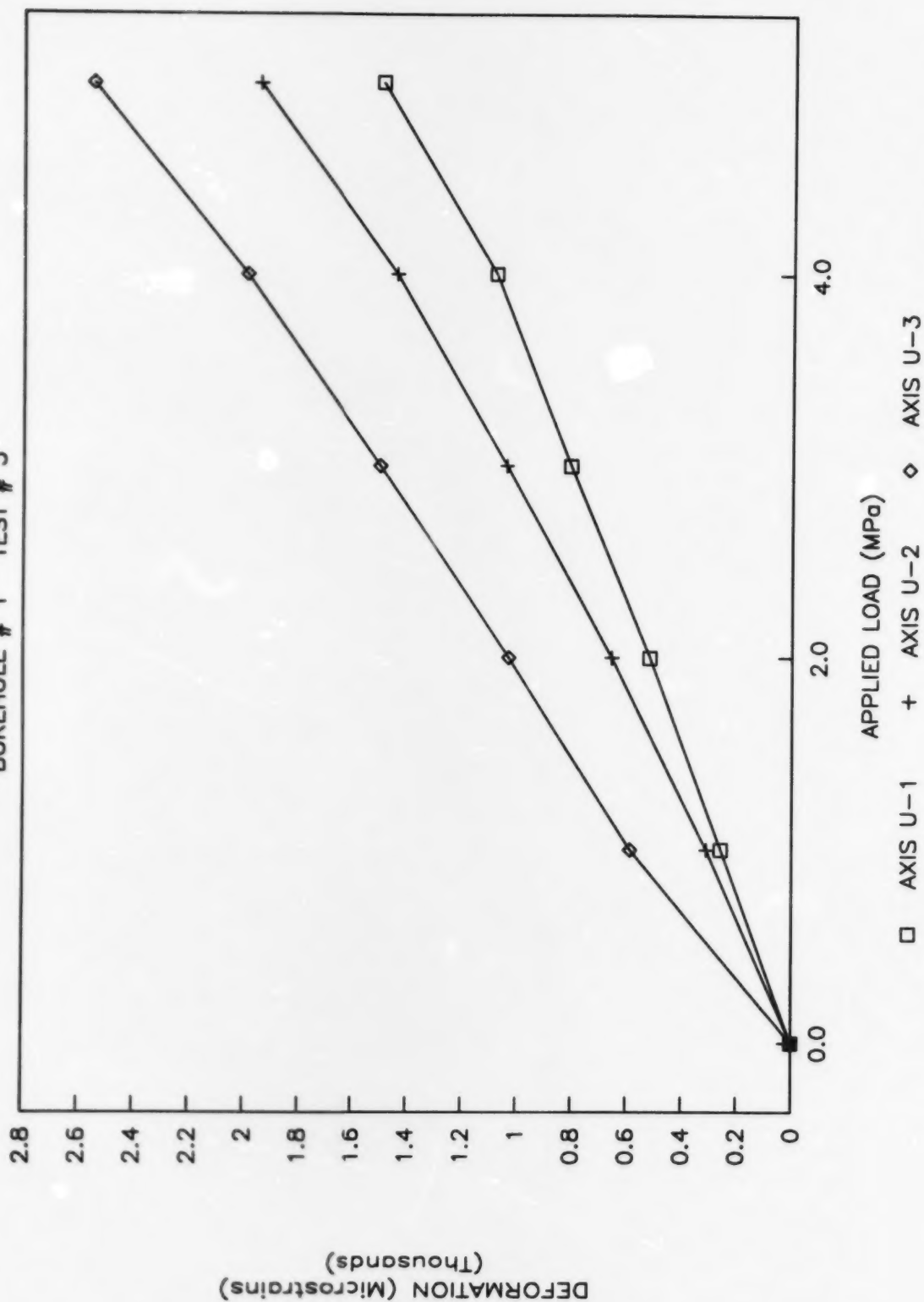
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BOREHOLE # 1 TEST # 4



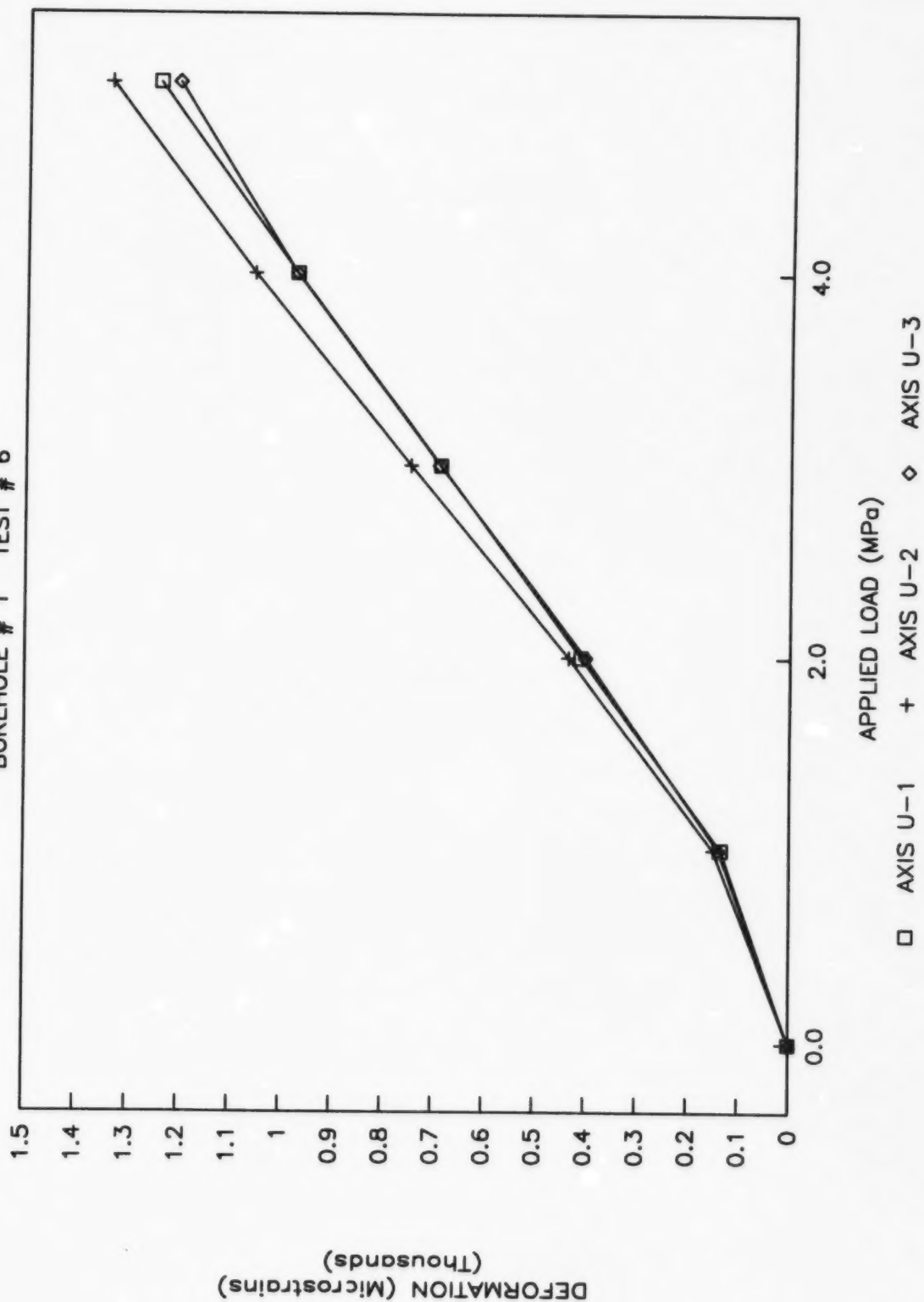
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 5



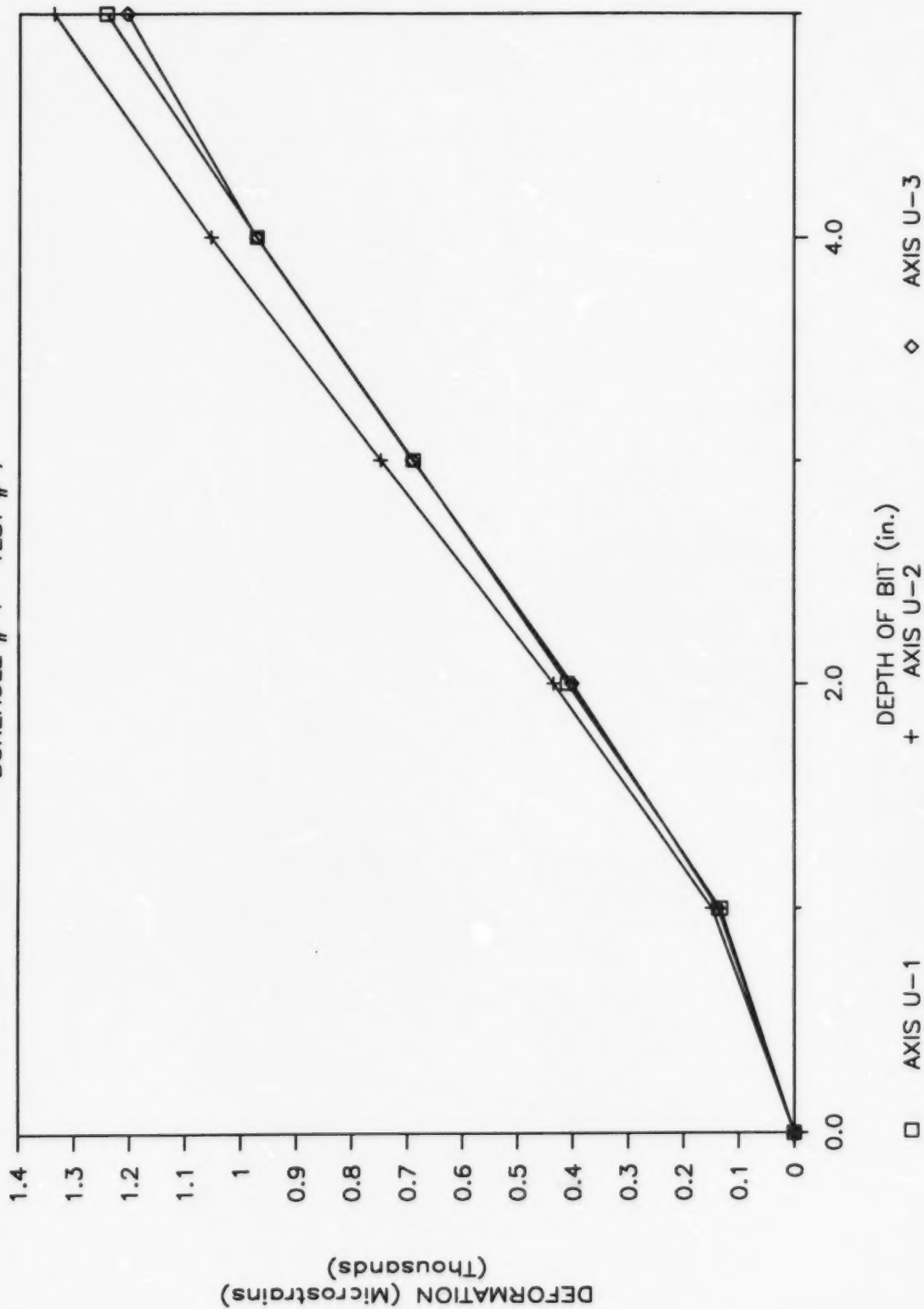
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BOREHOLE # 1 TEST # 6



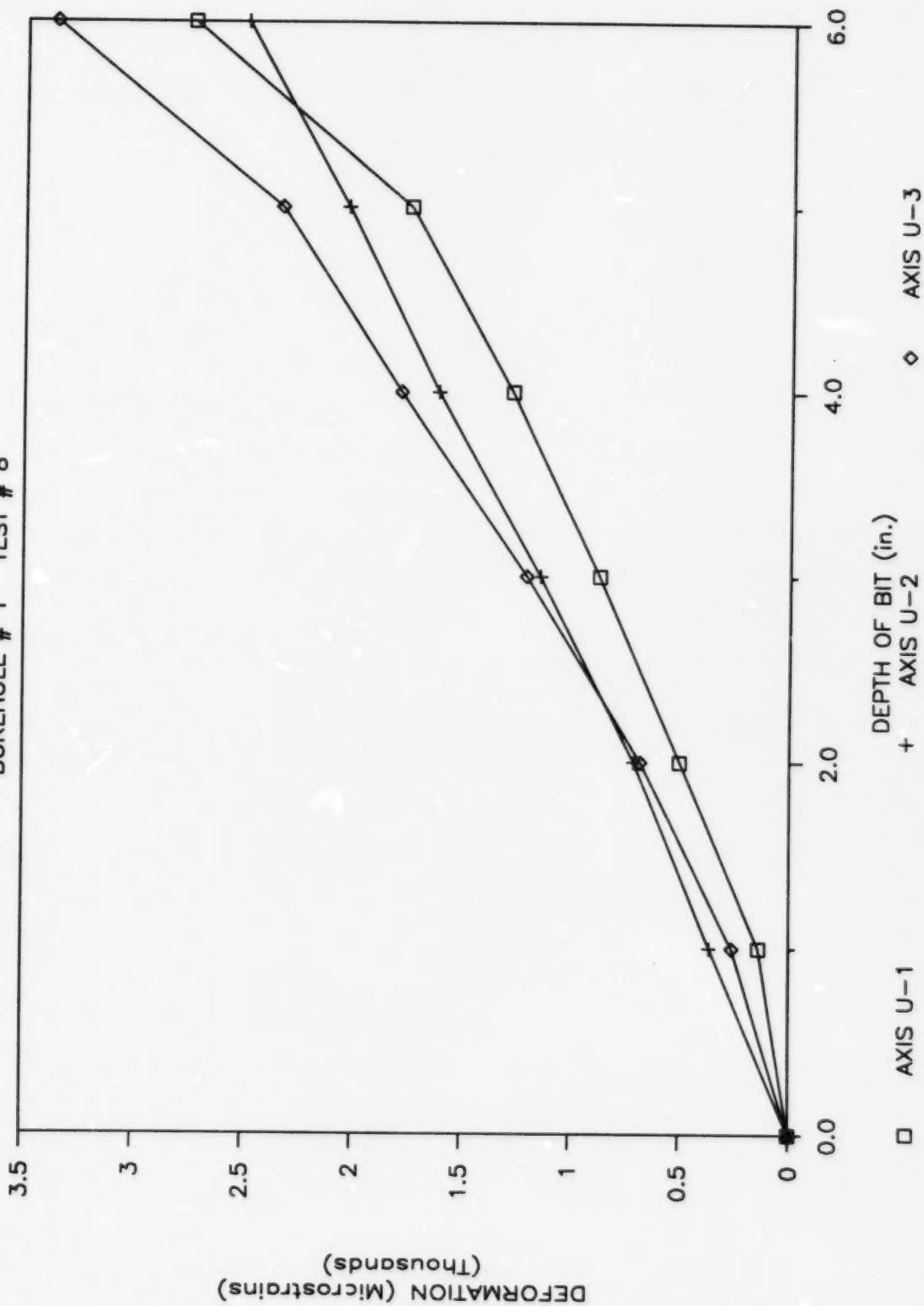
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BOREHOLE # 1 TEST # 7



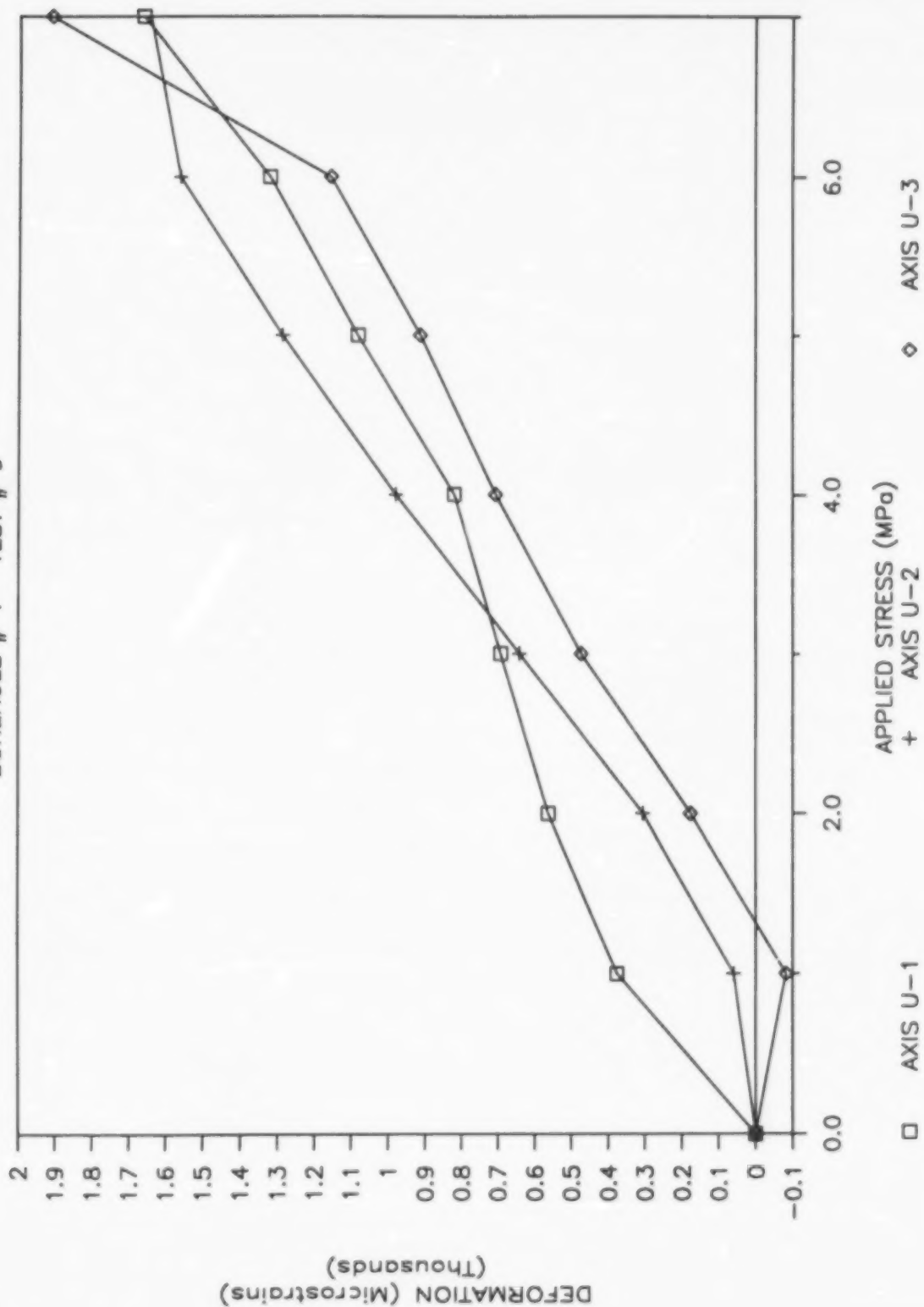
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 8



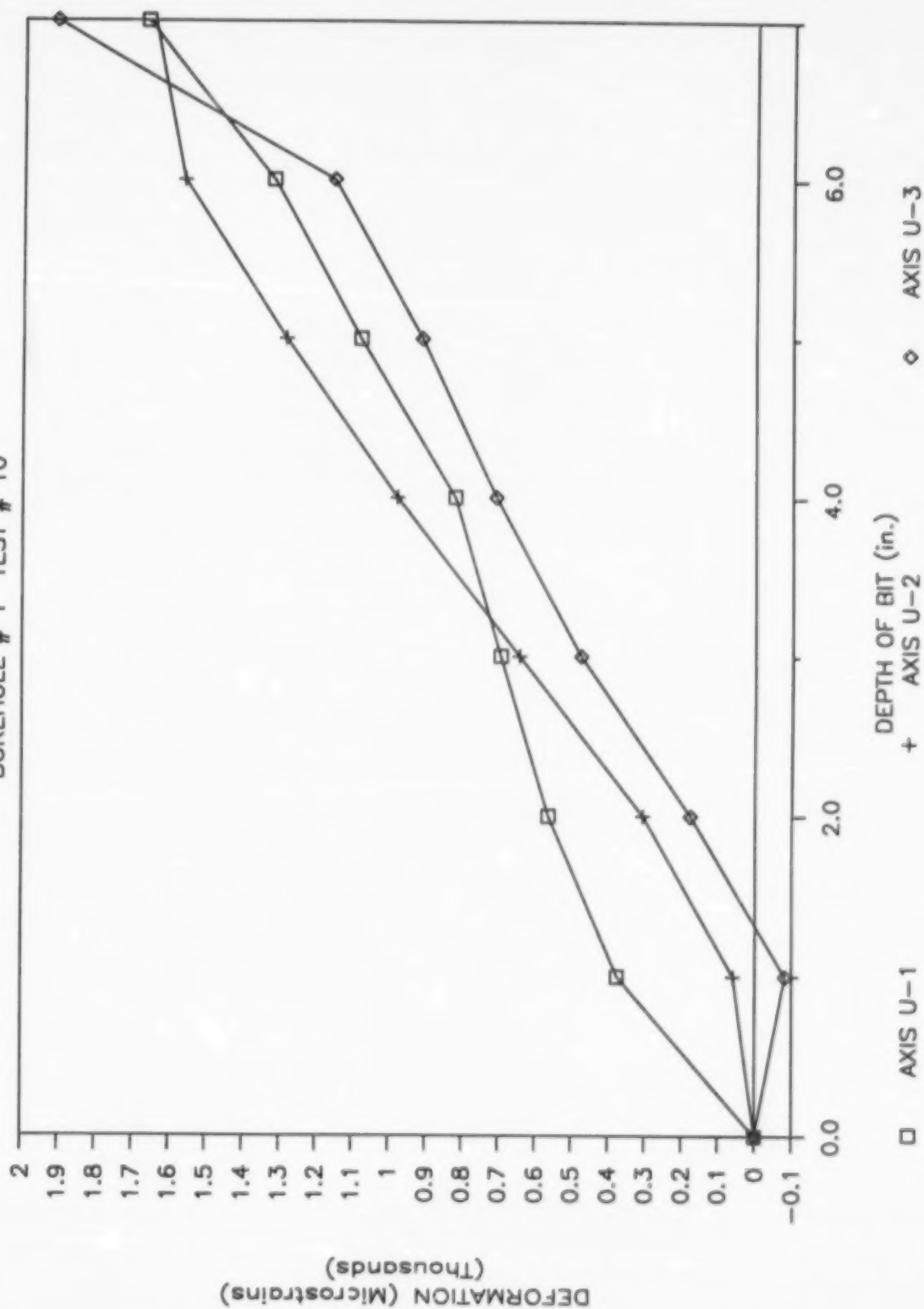
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BOREHOLE # 1 TEST # 9



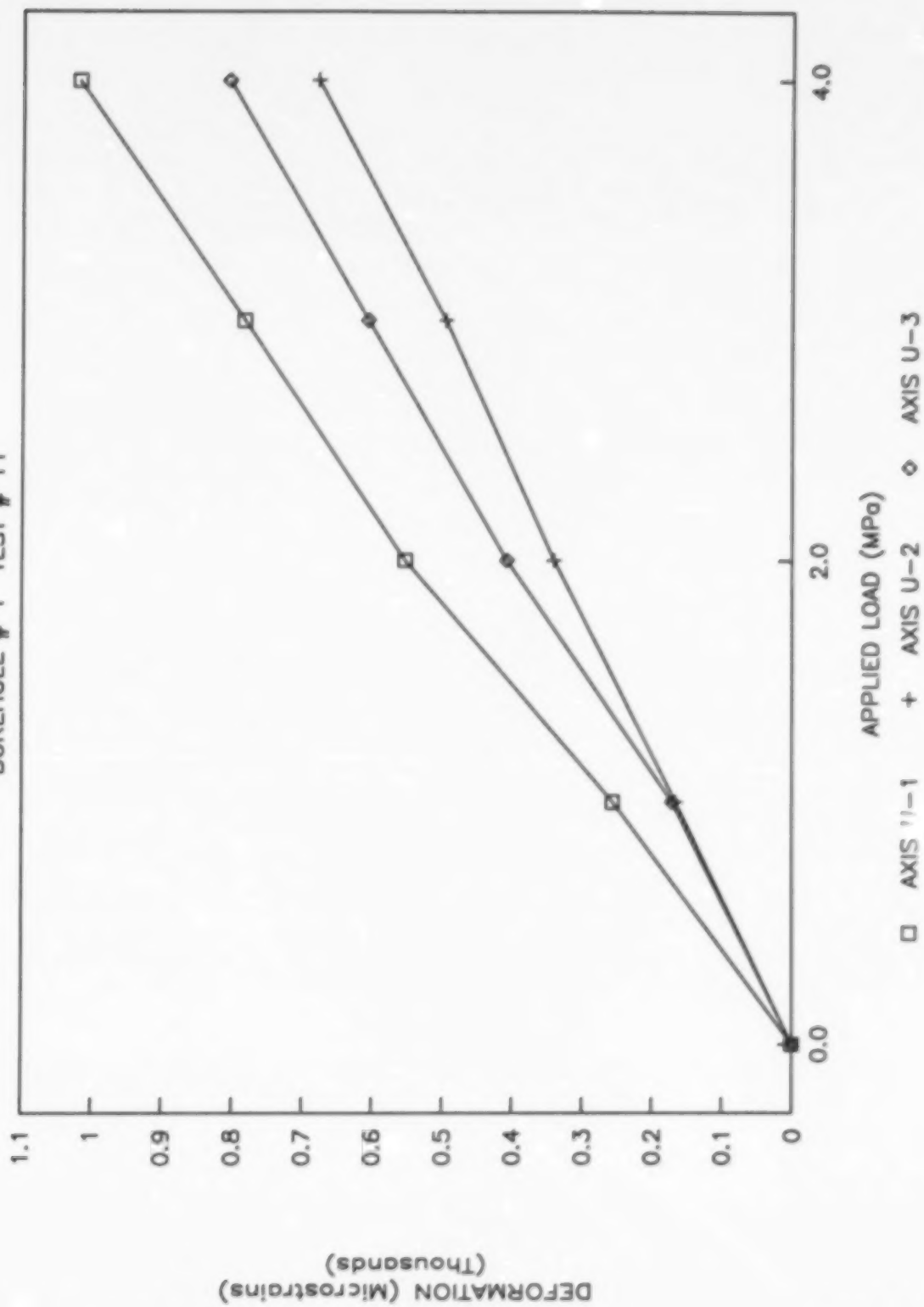
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BOREHOLE # 1 TEST # 10



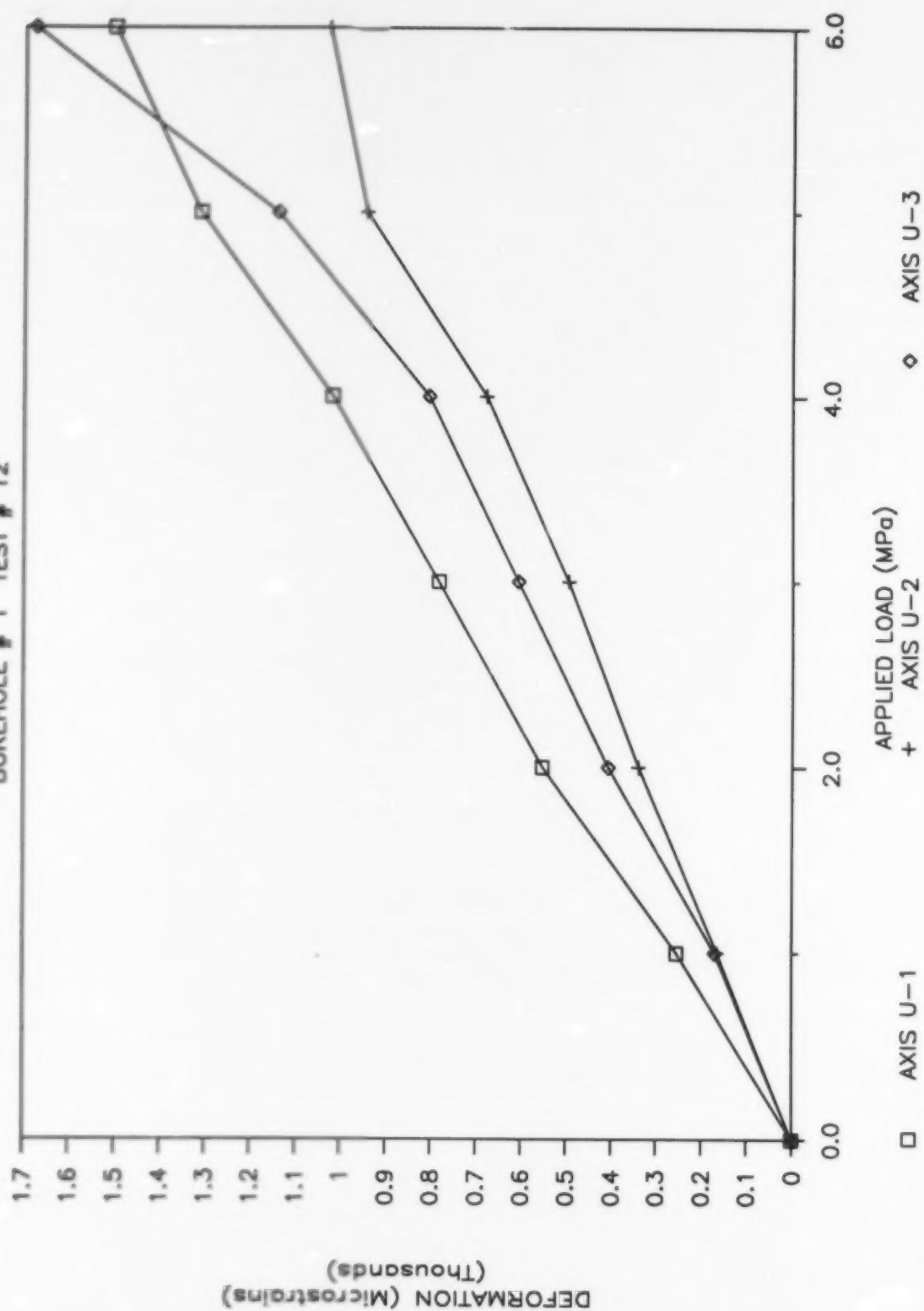
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BOREHOLE # 1 TEST # 11



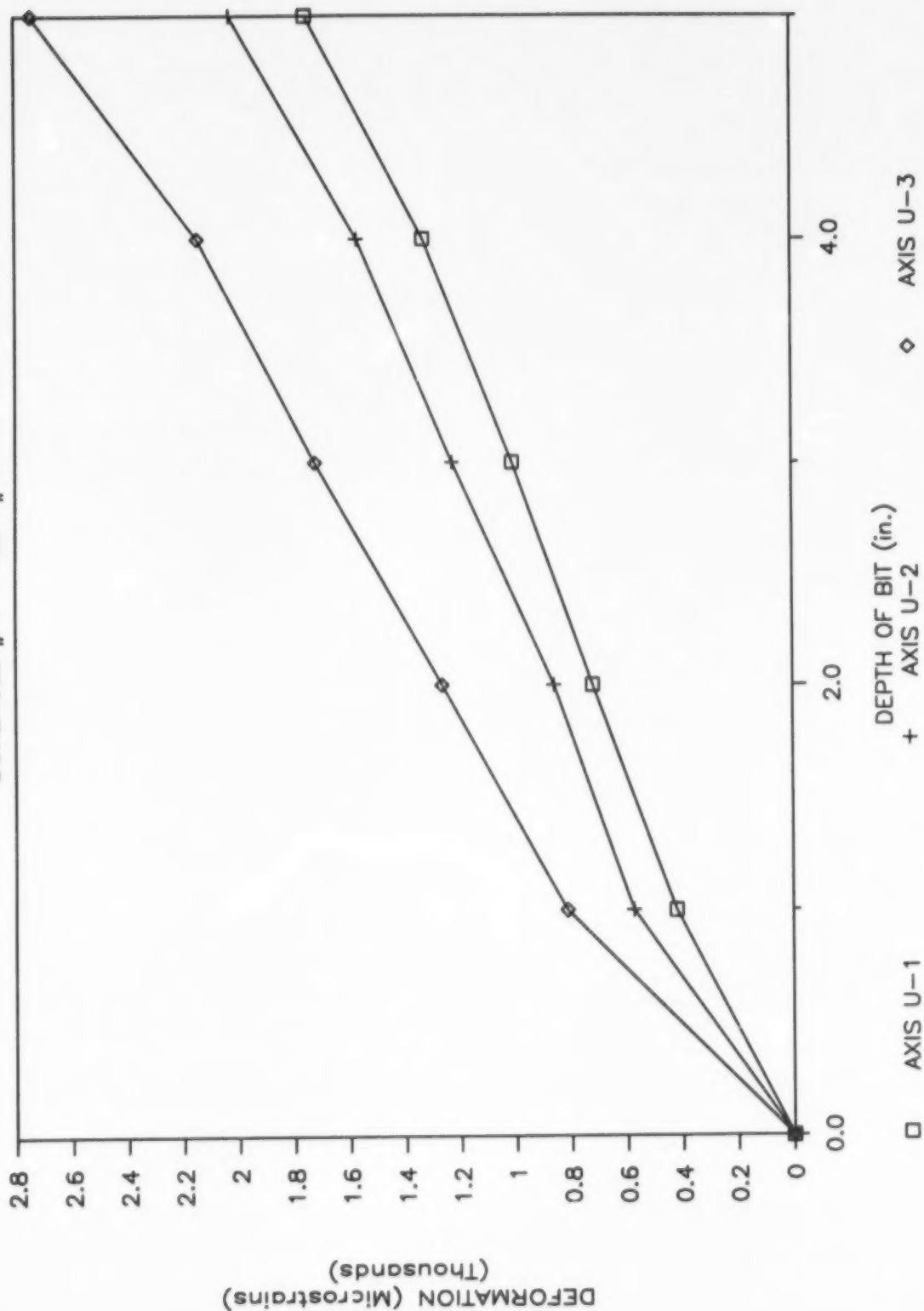
KIPLING COMPLEX BLDG KJ NOV.1989

BOREHOLE # 1 TEST # 12



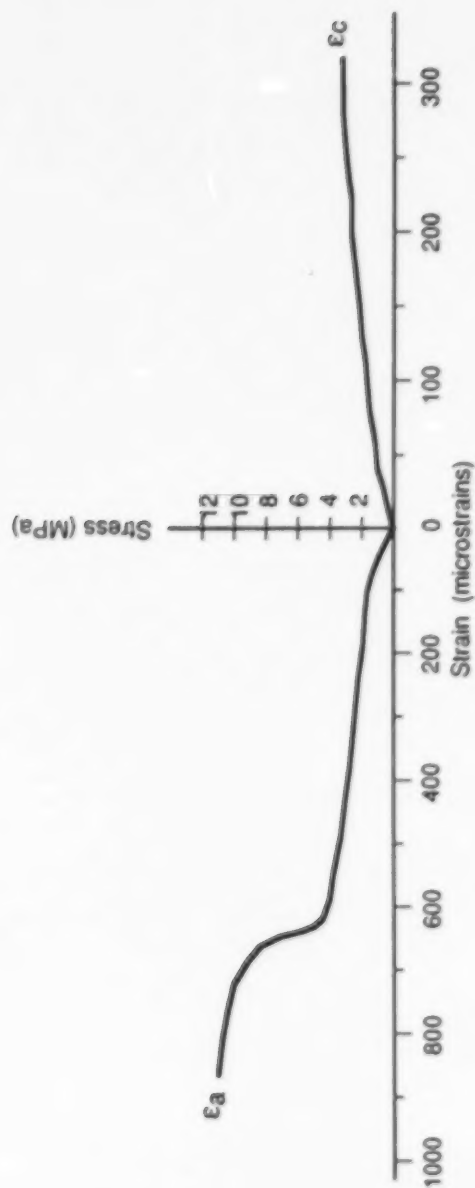
KIPLING COMPLEX BLDG KJ NOV. 1989

BOREHOLE # 1 TEST # 1



APPENDIX 5

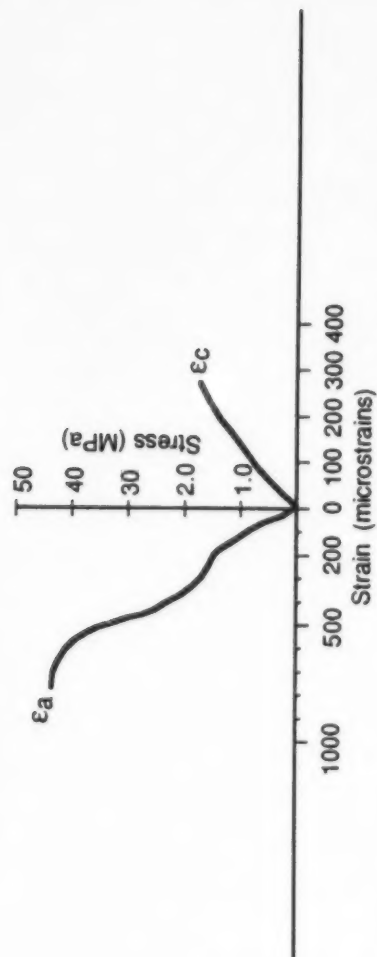
**STRESS-STRAIN CURVES FOR
UNIAXIAL COMPRESSION TESTS**



ϵ_a = Axial Strain

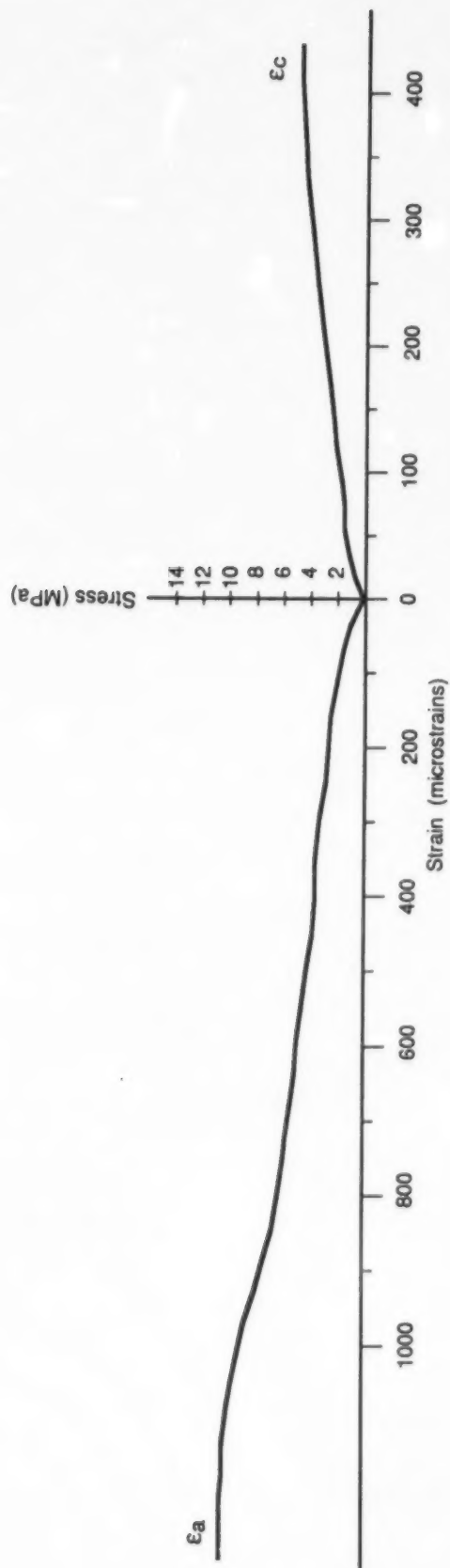
ϵ_c = Circumferential Strain

KIPLING COMPLEX - BUILDING KG
BOREHOLE 1, SAMPLE 1
DEPTH : 17.68 - 17.83 m



ϵ_a = Axial Strain
 ϵ_c = Circumferential Strain

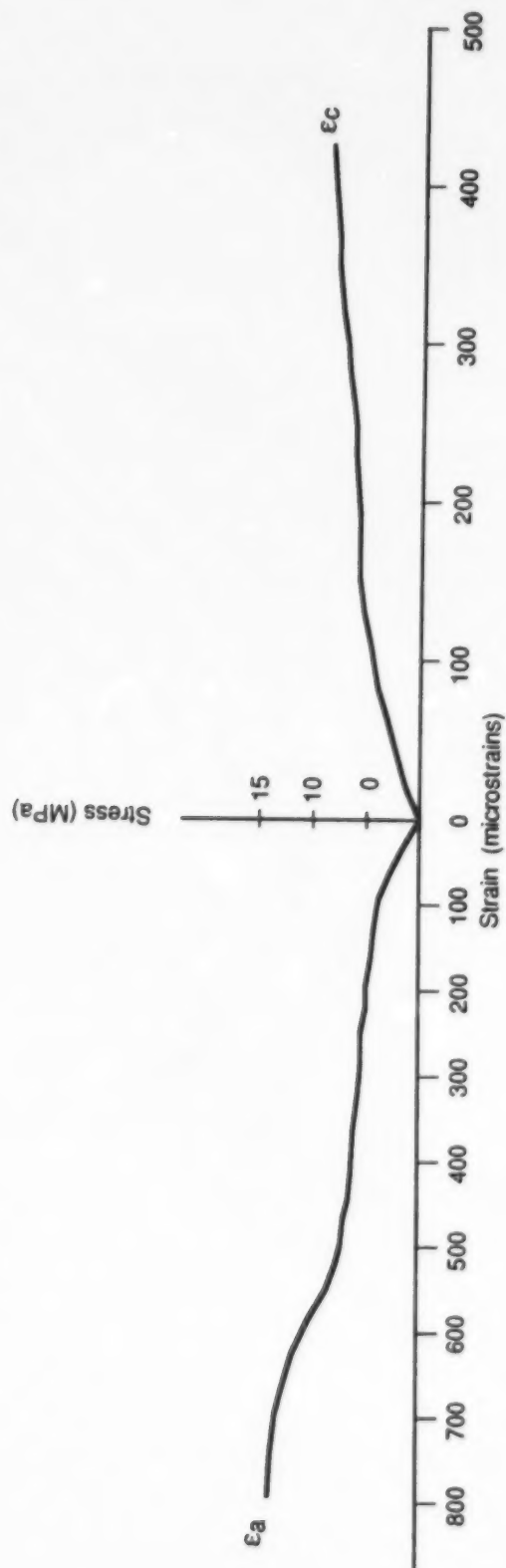
KIPLING COMPLEX - BUILDING KG
 BOREHOLE 1, SAMPLE 4
 DEPTH : 22.40 - 22.50 m



ϵ_a = Axial Strain

ϵ_c = Circumferential Strain

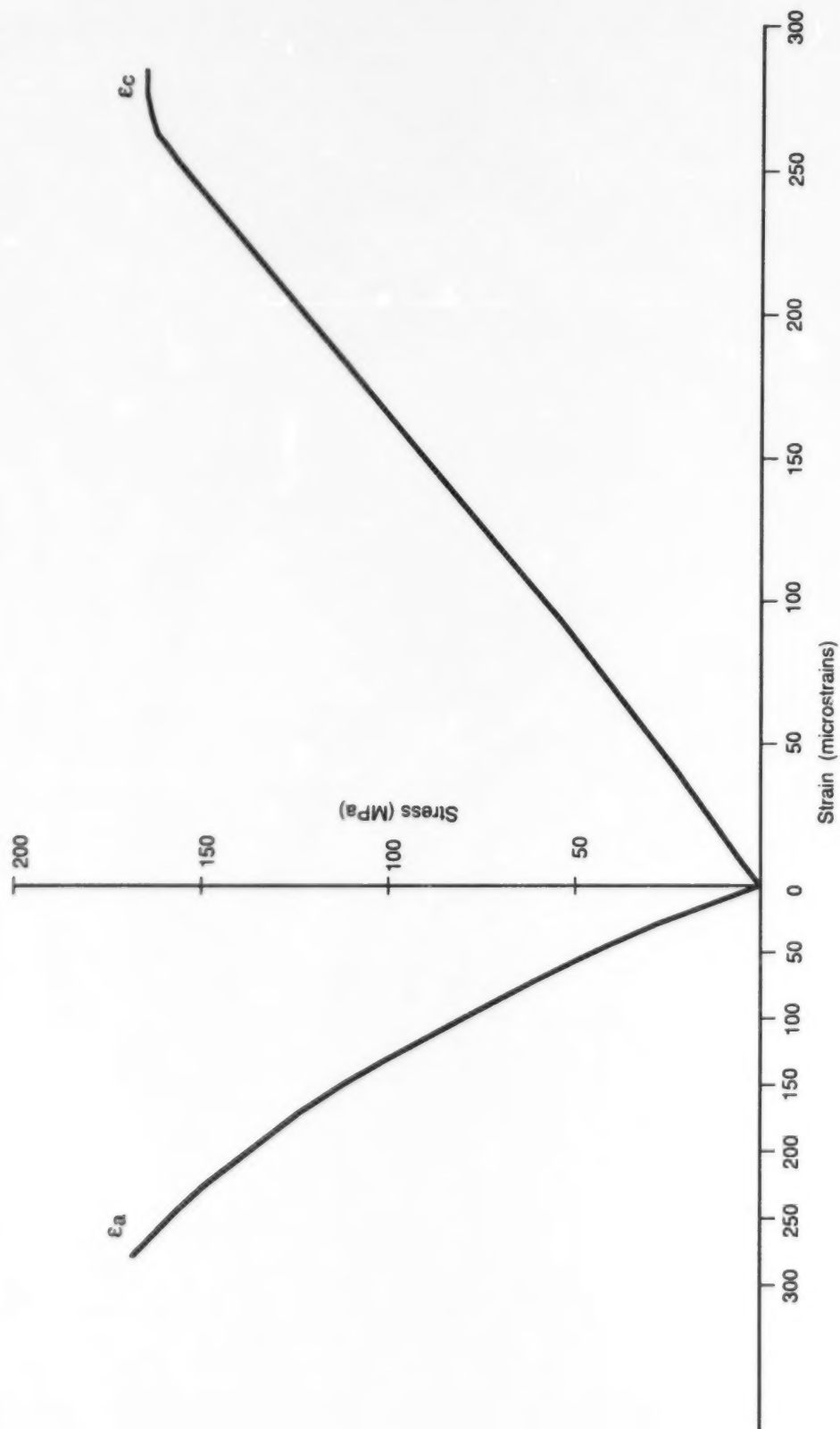
KIPLING COMPLEX - BUILDING KG
BOREHOLE 1, SAMPLE 4
DEPTH : 22.50 - 22.60 m



ϵ_a = Axial Strain

ϵ_c = Circumferential Strain

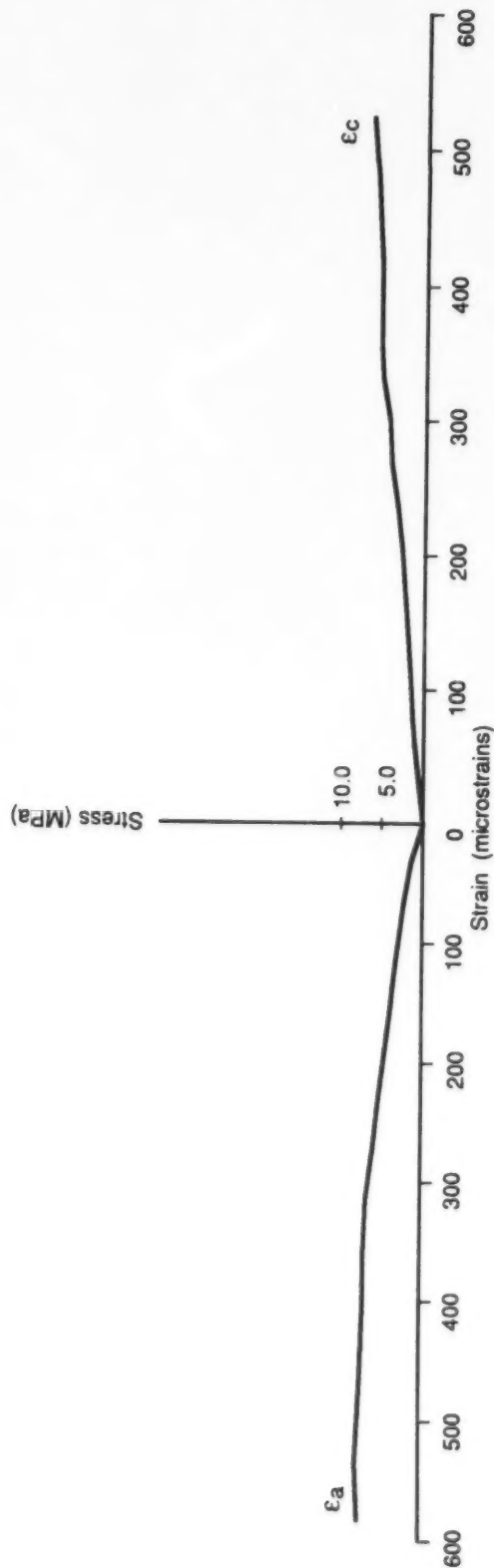
KIPLING COMPLEX - BUILDING KG
BOREHOLE 2, SAMPLE 2B
DEPTH : 12.93 - 13.23 m



ϵ_a = Axial Strain

ϵ_c = Circumferential Strain

KIPLING COMPLEX - BUILDING KG
BOREHOLE 2, SAMPLE 5
DEPTH : 19.29 - 19.41 m



ϵ_a = Axial Strain

ϵ_c = Circumferential Strain

KIPLING COMPLEX - BUILDING KG
BOREHOLE 2, SAMPLE 7
DEPTH : 22.88 - 23.42 m